Popular Astronomy.

Vol. III. No. 3. NOVEMBER, 1895. Whole No. 23.

THE VARIATION OF LATITUDE.

ERIC DOOLITTLE.

FOR POPULAR ASTRONOMY.

There is perhaps no recent event in mathematical astronomy which has excited such general interest as the discovery of the continuous variation of latitude. It constitutes a triumph of patient and laborious observations, which in this case were continued through many years, and in a no less degree a triumph of skillful mathematical analysis.

To discover and exhibit clearly this law from the mass of observations which had accumulated, required, not only mathematical ability of a high order, but also a rare judgment; in such degree, that though Peters, Hubbard, Nyren and Küstner had severally made the attempt, they had been unsuccessful.

It was inevitable, that a variation necessarily affecting so great a number of observations should frequently have made itself felt. It was early shown also that the disturbances might be explained by a change of latitude, but no law of change could be discovered. The quantities involved were, indeed, so small, that it was believed no absolute change of latitude could be certainly detected.

Until the year 1888, latitude was therefore considered invariable. But in that year there appeared a memoir by Dr. Küstner, based on observations made four years earlier, at Berlin, in which it was clearly proved, after an examination of all possible sources of error, that the hypothesis of a variable latitude must be made.

Dr. S. C. Chandler, from observations, also made in 1884-5, had discovered an apparent progressive change. He now re-attacked the problem. He subjected to a most exhaustive examination and discussion practically all of the available observations which have been made since instrumental refinements have made precision possible.

Of the success of this great work it is not necessary to speak: it is probably known to all of the readers of POPULAR ASTRONOMY.

We will describe briefly his remarkable discoveries.

If we imagine a line drawn through the center of the Earth, joining the points of greatest flattening, we have the *axis of figure* of the Earth. The extremities of this axis may be called the *poles of figure*.

Dr. Chandler has shown that the Earth does not rotate about this axis. Its *axis of rotation* is another line, also passing through its center and maintaining always the same direction in space, but which is continually moving about the axis of figure.

Euler had shown during the last century, that if the Earth were perfectly rigid, the pole of rotation would revolve in a circle about the pole of figure in a period of 305 days.

It was the constant effort to find a period agreeing with this theoretical value which misled the earlier astronomers. When, however, Chandler began to investigate the question, he set theory aside and sought a determination of the motion directly from the observations themselves. A comparison of simultaneous observations from three pairs of stations revealed, in the very beginning, that Euler's theoretical value was not even approximately the true one.

In the summer of 1892, after a years further study, it became evident that the motion, instead of being in a mere circle, was a complex one, being made up of at least two superposed motions.

That is, the pole of rotation moved as if in a small circle, while at the same time the circle was carried around the pole of figure.

The period of revolution in the small circle was about 428 days, while the circle was carried around the pole of figure in about one year. Both of these periods were subsequently found to vary; the former between 423 and 434 days, and the latter between about 361.0 and 369.5 days, during a long period of about 66 years.

There is an encouraging circumstance in connection with the the refinement of these motions. The results would have been far less complete and successful had it not been for a series of almost forgotten observations taken by Pond of the Greenwich Observatory in 1825-35. In 1823 an attempt was made in the *Philosophical Magazine* to annoy and discredit Pond by calling the accuracy of his work in question, and now after sixty years this accumulation of ten years of observations is just beginning to yield a part of its priceless information. This is a striking commentary on the enduring value of careful and truthful work.

Further research in 1894, revealed that the path in which the circle moved about the pole of figure, was elliptical, having major and minor axes of about 0″.22 and 0″.08, respectively; that is, of about 25 feet and 8 feet.

The entire motion, as discovered up to this time, was then the following:

The pole of rotation may be considered as revolving in a small circle of about 14 feet radius; the motion is from west to east, with an average period of 428.6 days.

The center of the circle is carried from west to east around the circumference of an ellipse in an average period of one year. The center of this ellipse is at the pole of figure, and its major axis is inclined (1894) at an angle of about 45° with the Greenwich meridian.

The motion of the circle about this circumference is central; that is, the radius vector describes equal areas in equal times.

The period of revolution in the circle varies between 423 and 424 days, and the radius also varies from about 8 to 18 feet, the period of these changes being 66 years.

There are apparently simultaneous changes in the elements of the elliptic orbit, but whether they are due to real changes in its form or to a revolution of the line of apsides is not yet determined. These changes are complementary to those in the circle.

It may well be imagined that the path resulting from these motions is a very complex one. It is shown in the accompanying figure.

A is the pole of figure. The circles directly on the path, mark the theoretical positions of the pole of rotation at intervals of 50 days, and those connected with them show the positions derived from observation.

The line *AD* is the meridian of Greenwich; *AW* and *AE* are the meridians of 90°, west and east longitute, respectively.

The marginal figures give the dimensions in seconds of arc; one tenth of one second is equivalent to about ten feet.

Dr. Chandler says: "As an ocular demonstration of the correctness of the theory and its close adherence to the very involved track of the pole as shown by the observations, this diagram is very convincing."

Theory indicates that the course of the curve will next be a series of gradually enlarging elliptical figures, whose longer axes will lie at right angles to those in the diagram.

The latest results, as yet unpublished, from the work which is being carried on at Bethlehem, Pa., indicate that the pole is following the above path very closely.

The figure is interesting also for another purpose; that is, to give the variation of latitude from the mean at any place for any time.

To find this, it is merely necessary to draw a line through *A* in

the direction of the station, and let fall a perpendicular upon it from the required point in the path: the distance from the foot of the perpendicular to *A* will be the change of latitude, — if the perpendicular falls between *A* and the station; otherwise +.

The construction in the figure is for 1895.5 at Bethlehem, and indicates that the departure, *AN*, from the mean latitude is — 0″.15; and this amount is rapidly increasing.

The above is a substantially complete description of the present movement of the pole of rotation. There is, however, distinct evidence of still a third motion; namely, that which would be produced if the center of the ellipse should move about in a circumference of probably 10 or 15 feet radius during a period of not far from twelve years.

It will be a matter of the greatest interest to see how closely future observations conform to these results.

And here there arises a most difficult and interesting problem for the attention of the dynamical astronomer.

If these changes continue thus regularly year after year, it will be perfectly evident that they cannot be due to such fortuitous causes as the movement of winds or water on the Earth. Even if, as is not certain, the 428 days is a modification of the Eulerian period, the cause of the change must be sought. A paper has already appeared on this subject by R. S. Woodward (*Astronomical Journal*, No. 345) in which, "Assuming that the changes are not due to causes external to the Earth," he starts with "The comprehensive hypothesis that the Earth is a body of variable form, or at least that some portions of the Earth's mass are subject to changes in relative positions."

There remains only to speak of a striking confirmation of these results from an unexpected quarter.

It was early pointed out by *Newcomb*, that during the revolutions of the Earth's axis of rotation, there should be a corresponding oscillation of the mean sea level which might be detected by a study of tidal observations. Thus, low tide at any station should occur when the pole of rotation lies between the station and the pole of figures; that is, when the station has its maximum latitude.

In response to this ingenious suggestion, the records of three stations were reduced and examined; two on the Pacific coast, extending over a period of 35 years, and one on the coast of Maine, at which the record had been taken for 18 years. The combination of the two series gave a mean time of oscillation of 431 ± 4 days, "the epochs of maxima and minima being entirely

harmonious." These observations are however exceedingly delicate; the whole variation on the Pacific and Atlantic coasts being only one and one-third, and one inches respectively.

A similar examination of tidal observations made near Amsterdam, between the years 1855 and 1892, were in satisfactory accord with the American observations, though the range of variation was there but two-thirds of an inch.

In both cases the epochs, as well as the dates of low tide, show a remarkable agreement with those derived from the theory of latitude variation. *Chandler* says in the *Astronomical Journal* of August 15:

"Notwithstanding the natural distrust attaching to investigations so delicate, upon a phenomenon almost evanescent in character, the harmony between the results of tidal and astronomical observation can hardly be regarded as fortuitous."

UNIVERSITY OF CHICAGO,
Sept. 26, 1895.

THE SCIENTIFIC VALUE OF A TOTAL LUNAR ECLIPSE.

CAROLINE E. FURNESS.

FOR POPULAR ASTRONOMY.

Twice during the present year we have been afforded the opportunity of seeing a total lunar eclipse. This wonderful phenomenon, though not so rare nor important as even a partial solar eclipse, is still infrequent enough to arouse great popular interest. To the untutored mind it is the most striking proof of the power of man to predict events involving the movements of the heavenly bodies. To the scientific astronomer the wonder excited may seem incommensurate to the difficulty of the computation, but when we consider the phenomenon itself, we are no longer surprised. Imagine the full Moon at midnight sailing high in a cloudless sky.

> "The Moon doth with delight
> Look round her when the heavens are bare."

She floods the whole landscape with a silvery light. No stars save the brightest can face her in her full glory. As we wait, all Nature seems hushed and expectant. At the watched-for moment, a break is seen in the round edge of the Moon. Gradually darkness spreads over her face, the stars come out one by one, and after a time, the silvery light is gone, the Earth is dark, the

Moon no longer shows her fair familiar aspect, but in the sky there is a dull coppery disc, a strange visitor in our heavens. An hour or two we wait, and then the shadow shows a glimmer of light at its edge; the glimmer widens and the shadow passes away as slowly as it came. The stars which ventured out grow pale and fade away, and soon the Moon in all her glory again reigns, the queen of the heavens. What wonder the savage Indians worshiped Columbus when he foretold to them that their moon-god would grow dark and lose his power!

But this kind of observation is not scientific. The astronomer, shut in his dome, with his eye at the telescope, sees but one part of the Moon at a time; he sees nothing of the beauty of the event. On the other hand, he is laying up a store of material which will enlarge our knowledge of the powers of nature, and which will reveal processes and results far more wonderful than the darkening of the Moon's face. It is profitable to consider some of scientific uses of a total lunar eclipse.

To the practical observer its value as the fulfillment of a prediction lies chiefly in the fact that it verifies theory and computation, but the exact agreement of predicted and observed times has no especial usefulness. The prediction is merely a matter of convenience. In former times the eclipse was applied largely to the determination of longitude. In becoming eclipsed the Moon passes into the shadow of the earth and actually loses its light. At the instant of totality it ceases to shine for all places on the hemisphere turned toward it. It is, then, an event in absolute time, and can therefore be used to obtain the difference of time between two places. This method is only an approximate one, because the instants of contact can not be noted accurately enough for a close determination of longitude. Often for an entire minute it is difficult to decide whether there is any light lingering about the edge of the Moon. This uncertainty is due to the atmosphere of the Earth. Those rays of sunlight which pass through it are partially absorbed; those at the upper edge lose but little of their light, and the amount of absorption is increased as the rays approach the surface of the Earth. Consequently there is a gradual darkening between the umbra and penumbra of the Earth's shadow, and hence great difficulty in deciding the exact second when the Moon has wholly entered the umbra. The passage of the rays of light through our atmosphere is also the cause of the variety of color seen during an eclipse; but this point will be considered later.

At the present time we employ a lunar eclipse for making cer-

tain observations which can best be made then, and for other work which is not possible at another time. The most important work, and one which demands the coöperation of observatories at widely distant places, is the observation of occultations. These occur at other times, but only the brighter stars can be followed to the Moon's limb and such stars are not frequent in its path. During an eclipse, however, stars down to the eleventh magnitude are easily followed until they disappear, and any star whose position is accurately determined is available. If an Observatory has undertaken the investigation of the Moon's place, it takes advantage of a total eclipse and prepares a list of stars which are to be occulted at other distant observatories, and sends a circular requesting observations. Such a circular was issued by the Imperial Observatoy at Kasan, Russia, for the eclipse of March 10th. The time of an occultation is much less difficult to determine than a contact of an eclipse. The Moon has no atmosphere, so that the star disappears instantaneously. In fact it disappears almost too quickly. It hangs like a bright bead on the limb of the Moon, and while one is still admiring it, it is gone. To a novice the surprise of the sudden disappearance interferes seriously with the accuracy of his observation.

An occultation may be used for two purposes. We may determine the longitude of an unknown place, and we may obtain corrections to the tabular values of the Moon's distance and diameter, right ascension and declination. These tabulated values of the Moon have been largely computed from meridian observations, which are subject to a much larger error than an occultation. It is for this reason, in addition to the fact that the star's place can be obtained with precision, that we can correct one set of observations by the other.

The equation which expresses the condition that an occultation will occur contains terms involving the position of the star, of the place of observation of the Moon, and the Moon's semi-diameter. Of these quantities, the right ascension and declination of the star must be exact, and this necessitates the use of a star whose coördinates have been determined with great accuracy. The geocentric latitude, the Earth's radius and the sidereal time of observation must be known exactly and the longitude approximately. From this fundamental equation is obtained another which contains the longitude expressed in terms of several unknown quantities, and these unknown quantities involve the various corrections to the Moon's values. If but one event, immersion or emersion, is observed at two places, one of which

has its longitude well determined, we obtain two equations, one of them containing the unknown longitude with certain corrections, and the other the known longitude with the same corrections. In order to solve these equations, we must make all the unknown quantities vanish except two. To do this, we consider the tabular values of the Moon exact. We can then solve the equations and find the longitude. If both immersion and emersion are observed at both places, we have four equations. If we increase the number of stars observed we increase the number of equations and may therefore determine all the unknown quantities with great accuracy by the method of least squares, and find the corrections to the tabular values.

Spectroscopically an eclipse is of decided interest. The spectrum of our atmosphere is full of lines which interfere with the complete identification of many solar lines. We do not usually get a sufficient thickness of air to examine the telluric lines satisfactorily. During an eclipse whatever light falls upon the Moon comes from rays which have passed tangent to the Earth through a great thickness of atmosphere and are thereby refracted, so that they fall upon the Moon. This light is reflected to us, and we receive rays which have come through a very great thickness of air. However, the benefit derived from the increased depth of air is much lessened by the faintness of the light emitted by the Moon.

Another question which has been investigated by some astronomers, notably Lord Rosse and Langley, is the amount of heat given out by the Moon. In order to decide how much of the heat is reflected, and how much is absorbed by the Moon and then radiated, observations made during an eclipse may be of great use, since at that time practically no heat is reflected. The observation is a very delicate one to make, and no really satisfactory results have been obtained. Lord Rosse's work so far seems to show that the heat diminishes almost as rapidly as the light does, showing that the heat we receive is almost entirely reflected. This result has been neither verified nor disproved by other observers.

The color of the Moon is worth noting, especially since it varies at different eclipses. Last March the Moon presented a beautiful combination of copper color, mingled with dull gray and green. In September the green was absent; that part of the shadow near the edge was gray shading into a dull red brown toward the center, with scattered patches of a lighter color. As has been suggested, it would be interesting in connection with the color of

the eclipsed Moon, to know the state of the atmosphere on that part of the Earth through which the outermost rays of light passed. The theory has been advanced that the Moon is self-luminous from the rays of sunlight which fall upon it, and that it has thus risen to a dull red heat. This theory is not supported by measuremeats of the heat of the Moon's surface made at other times.

Another practical use made of the eclipses of the Moon, rather historical than astronomical, is in fixing dates in ancient history. The first Olympiad, the beginning of the Christian era, and the death of Augustus are some of the events whose dates have been settled by the occurrence of lunar eclipses. Mr. Stockwell has made several recent contributions to chronology by his studies of eclipses.

The eclipse of September was observed at Vassar College Observatory with satisfaction. The sky was perfectly clear and remained so during the entire evening. A rough preparation by the graphic method had been made for the identification of the stars to be occulted. The parallax of the Moon was computed for six hours including the period of totality, the corrected places obtained and plotted upon a chart, and a line drawn through them to represent the path of the Moon. On the same chart were placed the stars catalogued in the Southern Durchmusterung. Then a paper disc with a radius equal to the Moon's augmented semi-diameter was moved along the path of the Moon, thus giving the times of occultation and the position angles of the stars occulted. Ten occultations were observed, including immersions and emersions. At the times of observation the magnitudes and position-angles were estimated and the stars afterwards identified with those on the chart. It is interesting to note that during totality the magnitudes were estimated pretty correctly, but before totality began, and just before it ended, they were all too faint. It is quite difficult to decide the magnitude of a star when there is any change in the general illumination of the field.

The method of recording is worth mentioning as it may be suggestive to other observers. The sidereal clock of the Observatory was away undergoing improvement, and there is no way of connecting the mean time chronometer with the chronograph. To avoid the eye-and-ear method, in the use of which we are at present out of practice, a recorder was placed by the chronometer and directed to tap with her finger at the end of every two seconds. To lessen the wearisomeness of recording during the entire evening, the observer called out just before an event oc-

the direction of the station, and let fall a perpendicular upon it from the required point in the path: the distance from the foot of the perpendicular to *A* will be the change of latitude, — if the perpendicular falls between *A* and the station; otherwise +.

The construction in the figure is for 1895.5 at Bethlehem, and indicates that the departure, *AN*, from the mean latitude is — 0″.15; and this amount is rapidly increasing.

The above is a substantially complete description of the present movement of the pole of rotation. There is, however, distinct evidence of still a third motion; namely, that which would be produced if the center of the ellipse should move about in a circumference of probably 10 or 15 feet radius during a period of not far from twelve years.

It will be a matter of the greatest interest to see how closely future observations conform to these results.

And here there arises a most difficult and interesting problem for the attention of the dynamical astronomer.

If these changes continue thus regularly year after year, it will be perfectly evident that they cannot be due to such fortuitous causes as the movement of winds or water on the Earth. Even if, as is not certain, the 428 days is a modification of the Eulerian period, the cause of the change must be sought. A paper has already appeared on this subject by R. S. Woodward (*Astronomical Journal*, No. 345) in which, "Assuming that the changes are not due to causes external to the Earth," he starts with "The comprehensive hypothesis that the Earth is a body of variable form, or at least that some portions of the Earth's mass are subject to changes in relative positions."

There remains only to speak of a striking confirmation of these results from an unexpected quarter.

It was early pointed out by *Newcomb*, that during the revolutions of the Earth's axis of rotation, there should be a corresponding oscillation of the mean sea level which might be detected by a study of tidal observations. Thus, low tide at any station should occur when the pole of rotation lies between the station and the pole of figures; that is, when the station has its maximum latitude.

In response to this ingenious suggestion, the records of three stations were reduced and examined; two on the Pacific coast, extending over a period of 35 years, and one on the coast of Maine, at which the record had been taken for 18 years. The combination of the two series gave a mean time of oscillation of 431 ± 4 days, "the epochs of maxima and minima being entirely

harmonious." These observations are however exceedingly delicate; the whole variation on the Pacific and Atlantic coasts being only one and one-third, and one inches respectively.

A similar examination of tidal observations made near Amsterdam, between the years 1855 and 1892, were in satisfactory accord with the American observations, though the range of variation was there but two-thirds of an inch.

In both cases the epochs, as well as the dates of low tide, show a remarkable agreement with those derived from the theory of latitude variation. *Chandler* says in the *Astronomical Journal* of August 15:

"Notwithstanding the natural distrust attaching to investigations so delicate, upon a phenomenon almost evanescent in character, the harmony between the results of tidal and astronomical observation can hardly be regarded as fortuitous."

UNIVERSITY OF CHICAGO,
Sept. 26, 1895.

THE SCIENTIFIC VALUE OF A TOTAL LUNAR ECLIPSE.

CAROLINE E. FURNESS.

FOR POPULAR ASTRONOMY.

Twice during the present year we have been afforded the opportunity of seeing a total lunar eclipse. This wonderful phenomenon, though not so rare nor important as even a partial solar eclipse, is still infrequent enough to arouse great popular interest. To the untutored mind it is the most striking proof of the power of man to predict events involving the movements of the heavenly bodies. To the scientific astronomer the wonder excited may seem incommensurate to the difficulty of the computation, but when we consider the phenomenon itself, we are no longer surprised. Imagine the full Moon at midnight sailing high in a cloudless sky.

> "The Moon doth with delight
> Look round her when the heavens are bare."

She floods the whole landscape with a silvery light. No stars save the brightest can face her in her full glory. As we wait, all Nature seems hushed and expectant. At the watched-for moment, a break is seen in the round edge of the Moon. Gradually darkness spreads over her face, the stars come out one by one, and after a time, the silvery light is gone, the Earth is dark, the

Moon no longer shows her fair familiar aspect, but in the sky there is a dull coppery disc, a strange visitor in our heavens. An hour or two we wait, and then the shadow shows a glimmer of light at its edge; the glimmer widens and the shadow passes away as slowly as it came. The stars which ventured out grow pale and fade away, and soon the Moon in all her glory again reigns, the queen of the heavens. What wonder the savage Indians worshiped Columbus when he foretold to them that their moon-god would grow dark and lose his power!

But this kind of observation is not scientific. The astronomer, shut in his dome, with his eye at the telescope, sees but one part of the Moon at a time; he sees nothing of the beauty of the event. On the other hand, he is laying up a store of material which will enlarge our knowledge of the powers of nature, and which will reveal processes and results far more wonderful than the darkening of the Moon's face. It is profitable to consider some of scientific uses of a total lunar eclipse.

To the practical observer its value as the fulfillment of a prediction lies chiefly in the fact that it verifies theory and computation, but the exact agreement of predicted and observed times has no especial usefulness. The prediction is merely a matter of convenience. In former times the eclipse was applied largely to the determination of longitude. In becoming eclipsed the Moon passes into the shadow of the earth and actually loses its light. At the instant of totality it ceases to shine for all places on the hemisphere turned toward it. It is, then, an event in absolute time, and can therefore be used to obtain the difference of time between two places. This method is only an approximate one, because the instants of contact can not be noted accurately enough for a close determination of longitude. Often for an entire minute it is difficult to decide whether there is any light lingering about the edge of the Moon. This uncertainty is due to the atmosphere of the Earth. Those rays of sunlight which pass through it are partially absorbed; those at the upper edge lose but little of their light, and the amount of absorption is increased as the rays approach the surface of the Earth. Consequently there is a gradual darkening between the umbra and penumbra of the Earth's shadow, and hence great difficulty in deciding the exact second when the Moon has wholly entered the umbra. The passage of the rays of light through our atmosphere is also the cause of the variety of color seen during an eclipse; but this point will be considered later.

At the present time we employ a lunar eclipse for making cer-

tain observations which can best be made then, and for other work which is not possible at another time. The most important work, and one which demands the coöperation of observatories at widely distant places, is the observation of occultations. These occur at other times, but only the brighter stars can be followed to the Moon's limb and such stars are not frequent in its path. During an eclipse, however, stars down to the eleventh magnitude are easily followed until they disappear, and any star whose position is accurately determined is available. If an Observatory has undertaken the investigation of the Moon's place, it takes advantage of a total eclipse and prepares a list of stars which are to be occulted at other distant observatories, and sends a circular requesting observations. Such a circular was issued by the Imperial Observatoy at Kasan, Russia, for the eclipse of March 10th. The time of an occultation is much less difficult to determine than a contact of an eclipse. The Moon has no atmosphere, so that the star disappears instantaneously. In fact it disappears almost too quickly. It hangs like a bright bead on the limb of the Moon, and while one is still admiring it, it is gone. To a novice the surprise of the sudden disappearance interferes seriously with the accuracy of his observation.

An occultation may be used for two purposes. We may determine the longitude of an unknown place, and we may obtain corrections to the tabular values of the Moon's distance and diameter, right ascension and declination. These tabulated values of the Moon have been largely computed from meridian observations, which are subject to a much larger error than an occultation. It is for this reason, in addition to the fact that the star's place can be obtained with precision, that we can correct one set of observations by the other.

The equation which expresses the condition that an occultation will occur contains terms involving the position of the star, of the place of observation of the Moon, and the Moon's semi-diameter. Of these quantities, the right ascension and declination of the star must be exact, and this necessitates the use of a star whose coördinates have been determined with great accuracy. The geocentric latitude, the Earth's radius and the sidereal time of observation must be known exactly and the longitude approximately. From this fundamental equation is obtained another which contains the longitude expressed in terms of several unknown quantities, and these unknown quantities involve the various corrections to the Moon's values. If but one event, immersion or emersion, is observed at two places, one of which

has its longitude well determined, we obtain two equations, one of them containing the unknown longitude with certain corrections, and the other the known longitude with the same corrections. In order to solve these equations, we must make all the unknown quantities vanish except two. To do this, we consider the tabular values of the Moon exact. We can then solve the equations and find the longitude. If both immersion and emersion are observed at both places, we have four equations. If we increase the number of stars observed we increase the number of equations and may therefore determine all the unknown quantities with great accuracy by the method of least squares, and find the corrections to the tabular values.

Spectroscopically an eclipse is of decided interest. The spectrum of our atmosphere is full of lines which interfere with the complete identification of many solar lines. We do not usually get a sufficient thickness of air to examine the telluric lines satisfactorily. During an eclipse whatever light falls upon the Moon comes from rays which have passed tangent to the Earth through a great thickness of atmosphere and are thereby refracted, so that they fall upon the Moon. This light is reflected to us, and we receive rays which have come through a very great thickness of air. However, the benefit derived from the increased depth of air is much lessened by the faintness of the light emitted by the Moon.

Another question which has been investigated by some astronomers, notably Lord Rosse and Langley, is the amount of heat given out by the Moon. In order to decide how much of the heat is reflected, and how much is absorbed by the Moon and then radiated, observations made during an eclipse may be of great use, since at that time practically no heat is reflected. The observation is a very delicate one to make, and no really satisfactory results have been obtained. Lord Rosse's work so far seems to show that the heat diminishes almost as rapidly as the light does, showing that the heat we receive is almost entirely reflected. This result has been neither verified nor disproved by other observers.

The color of the Moon is worth noting, especially since it varies at different eclipses. Last March the Moon presented a beautiful combination of copper color, mingled with dull gray and green. In September the green was absent; that part of the shadow near the edge was gray shading into a dull red brown toward the center, with scattered patches of a lighter color. As has been suggested, it would be interesting in connection with the color of

the eclipsed Moon, to know the state of the atmosphere on that part of the Earth through which the outermost rays of light passed. The theory has been advanced that the Moon is self-luminous from the rays of sunlight which fall upon it, and that it has thus risen to a dull red heat. This theory is not supported by measuremeats of the heat of the Moon's surface made at other times.

Another practical use made of the eclipses of the Moon, rather historical than astronomical, is in fixing dates in ancient history. The first Olympiad, the beginning of the Christian era, and the death of Augustus are some of the events whose dates have been settled by the occurrence of lunar eclipses. Mr. Stockwell has made several recent contributions to chronology by his studies of eclipses.

The eclipse of September was observed at Vassar College Observatory with satisfaction. The sky was perfectly clear and remained so during the entire evening. A rough preparation by the graphic method had been made for the identification of the stars to be occulted. The parallax of the Moon was computed for six hours including the period of totality, the corrected places obtained and plotted upon a chart, and a line drawn through them to represent the path of the Moon. On the same chart were placed the stars catalogued in the Southern Durchmusterung. Then a paper disc with a radius equal to the Moon's augmented semi-diameter was moved along the path of the Moon, thus giving the times of occultation and the position angles of the stars occulted. Ten occultations were observed, including immersions and emersions. At the times of observation the magnitudes and position-angles were estimated and the stars afterwards identified with those on the chart. It is interesting to note that during totality the magnitudes were estimated pretty correctly, but before totality began, and just before it ended, they were all too faint. It is quite difficult to decide the magnitude of a star when there is any change in the general illumination of the field.

The method of recording is worth mentioning as it may be suggestive to other observers. The sidereal clock of the Observatory was away undergoing improvement, and there is no way of connecting the mean time chronometer with the chronograph. To avoid the eye-and-ear method, in the use of which we are at present out of practice, a recorder was placed by the chronometer and directed to tap with her finger at the end of every two seconds. To lessen the wearisomeness of recording during the entire evening, the observer called out just before an event oc-

curred and the tapping began and continued until the observation was ended. As there are two keys in the same circuit recording on the chronograph, this method was quite feasible.

For amateur observers the eclipse offers an opportunity for interesting observations. The students in astronomy at Vassar College predicted the eclipse as part of their regular course. Though it occurred during the vacation several of them observed the instants of contact and their times agreed fairly well with those of the Observatory.

While a lunar eclipse is not so important nor so much talked about as a solar eclipse it still serves several very useful purposes, as we have seen. The consideration of these has perhaps not been without profit to the amateur astronomer.

VASSAR COLLEGE OBSERVATORY,
October 4, 1895.

ALMANACS—IV.

R. W. McFARLAND.

FOR POPULAR ASTRONOMY.

The principal computations for an ordinary almanac are those for the rising and setting of the Sun and Moon. Some computors give the time of rising or of setting of a few of the more conspicuous stars, or of the planets, for a few times in a year; but most of them are content to give the name of the constellation in which the planets may be at the time. There is usually a column showing to the nearest minute the difference of time between the sun and the clock, generally headed "sun slow," or "sun fast"; the results of the computation usually being given in clock time, which is "mean" time. I have not in many years seen an almanac giving results in "solar time," although fifty years ago it was not uncommon. The figures in this column are taken directly from the Nautical Almanac.

The changes of the Moon and its eclipses are also taken directly from the Nautical Almanac, by subtracting the longitude of the place for which the small almanac is made; for Boston, Mass., taking $4^h\,44^m$; for Columbus, O., $5^h\,32^m$, etc.

There is also a column for the "moon's signs," in which some put the nearest degree of the right ascension of the Moon at noon of that day; others give merely the old astrological figure for two or three days as ♈, ♉, ♊,—the Moon being generally

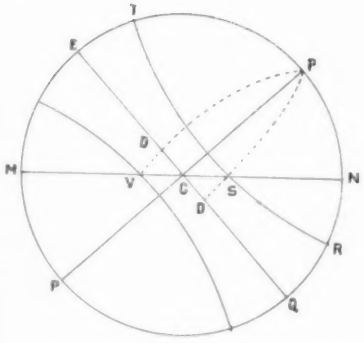
about two days and a half in one constellation or sign. This column is often consulted by those who believe in the efficacy of the Moon concerning all things terrestrial,—and these constitute a large majority of the farmers and gardeners of the United States. The publishers of almanacs in years past fully understood this fact, as mentioned in a previous article.—I had purposely omitted the column—the manuscript was returned to me, with a request that I fill the blanks, otherwise the firm would not be able "to give the almanacs away." Astrology takes no notice of *constellations*, only of *signs*. Most computors give the Moon's place in the constellation of the same name as the sign, but 30° away. This is a direct perversion of the whole question, but those who believe in the column do not know the difference,

"He that's robbed and knows it not, is not robbed at all."

If a little digression is allowable at this point, I would say that the cut of the eclipse of Sept. 3, given in the September number of this journal, is an excellent case for a learner to use in computing the several phases of an eclipse. If a fair draft is made, on a scale, say twice as large, one can tell the beginning or end of any phase, to the nearest minute, by measuring on a scale the distance from J to G, for the middle; from J to H, for the beginning; and from J to I, for totality—calling the distance OP sixty minutes. This degree of accuracy is sufficient for any practical purpose of an eclipse of the Moon—the lines of separation are not sharply marked,—and neither by the naked eye nor by the telescope can anyone tell to half a minute when any phase begins or ends. But the complete computation can be made by any one who understands plain trigonometry. The angle O is the only angle required; and the four lines CJ (which is perpendicular to the Moon's path), JG, JI, and JH, are to be computed. The acute angle at G is equal to the angle O; and CG is given in the elements. By trigonometry we get CJ and JG; then by the property of right angled triangles, we find JH and JI; drawing a line from C to H, this line CH is the sum of the radii of the shadow and of the Moon, and CI is the difference of the same two radii. Then $(CJ + CH)(CH - CJ)$ equals the square of JH; and similarly for JI. But a computor of almanacs does not take even this little labor,—it is not necessary for his purpose.

An eclipse of the Sun is a very different affair;—so much so that no explanation will be given here.

The rising and setting of the Sun is computed for every day of the year. It is a question of right angled triangles in spherical trigonometry. The cut may make it plain.



Let P be the pole of the celestial equator; EQ that equator seen edgewise; PEM a meridian; MCN the circle of the horizon seen edgewise, C being at the east point. From C to E is 90°; PCN is the latitude; the meridian may be revolved about the axis PP′. When it becomes perpendicular to the plane of the paper, it coincides with the circle PCP′; revolved still further, it may coincide with PSD. The meridian when revolved from its proper position is called an hour-circle. Fifteen degrees of the equator pass the meridian in one hour. When the Sun is on the equator it rises at C, six hours before noon. When the Sun is on the parallel TR, it rises at S; and this is before six by as long a time as it takes the point D to pass over DC, at the rate of 15° to one hour; DS is the declination of the Sun, and is given in the Nautical Almanac for noon of every day in the year. The latitude PCN is known; then its compliment SCD is also known. By Napier's rule of circular parts, when DS and the angle at C are known, CD is found by the equation R . sin CD = tan DS . cot SCD; but the cot. equals the tangent of PCN, the latitude. Calling CD the "time," we have the sine of the "time" before six o'clock equals the tangent of the declination multiplied by the tangent of the latitude. Suppose the latitude is 40°. The computer takes the tan. of 40° to three places of decimals, 9.924,—three decimals will give the time to the nearest minute. Suppose the dec. to be 10° 10′ north; its tan. to the nearest unit of the third place is 9.256; adding we have 9.180; in the table of sines we find 8° 43′; each degree gives 4 min. of time; 15′ of space gives 1 min. of time; wherefore if 8° 43′ is the equivalent of 35^{m}—so the Sun rises 35^{m} before six. This is for the middle of the Sun, no allowance being made for the semidiameter, or for refraction. The two causes make the Sun's upper limb rise about 4 min. earlier—or 39^{m} before six. The Sun sets as much after six as it rises before six,—so for that day the Sun rises at 5^{h} 21^{m}, and sets at 6^{h} 39^{m} (the two together making 12^{h},) solar time. To change to mean or clock time, suppose the Sun 2^{m} slow; then the rising would be 5^{h} 23^{m} by the clock, and the setting would be 2^{m} slow, or 6^{h} 41^{m} clock time; the sum of the two is 12^{h} 4^{m}—being greater than 12^{h} by double the

* Lower P in cut should have been P′.—Ed.

equation of time—which here is taken as 2^m. Had the Sun been fast, the sum would have been less than 12^h by double the time. If Sun time is taken, double the time of sunset gives the length of the day from sunrise to sunset; and double the time of rising gives the night, or time from sunset to sunrise.

Practically the computer very greatly abbreviates the above work. Adding the decimal .924 gives the same result as subtracting .076. So the computor picks out the tan. of the dec., mentally subtracts .076, looks for the corresponding sine, changes it to time, mentally, and from the almanac or a convenient table, applies the equation of time, and the four extra minutes for the rising of the Sun's upper limb.

In this way a moderately rapid computer in 3 hours can compute the rising and setting of the Sun for a year.

In the figure the equator is half below the horizon; all parallel circles north of the equator have more than half above the horizon; all south of the equator have less than half above. Consequently all celestial bodies north of the equator on places in north latitude, will be more than 12 hours above the horizon; and all south of the equator will be above the horizon less than 12 hours. In both cases half the times reduced to arc give what is called the semi diurnal arc,—*i. e.*, the time from the rising to the time of reaching the meridian, or the time from the meridian to the setting.

If a table of semi-diurnal arcs is made, say from 0° to 40°, then as soon as the declination of a body is known the table at once gives the rising or setting of that body when the time of passing the meridian is known,—except where the body itself is in relatively rapid angular motion.

Suppose, then, that a star or a planet has 30° of right ascension more than the Sun, and that its declination is 25° north. The body then arrives at meridian at 2 P. M.; the semi-diurnal arc for that decl. then gives the time of rising or of setting. For semi-diurnal arcs south of the equator, subtract the semi-diurnal arc north of the equator from 12^h, the remainder is the southern arc of the same degree. Venus and Mercury being always relatively near the Sun and having rapid motion, need a slight correction:—the Moon a very large correction for motion between the time of rising and of being on the meridian.

The calculation of the rising and setting of the Moon is far more troublesome than like calculations for the Sun, and that because of its rapid and irregular motion. There are several ways of finding the required hour. The following allows of rapid com-

putation when one wishes to compute for a year or longer period. Compute a table of semi-diurnal arcs from 0° to 28° 30′, at intervals of 10′. This will include the Moon for any year. The Moon's orbit being quite eccentric the motion is subject to great variations. The interval from the hour of its passing the meridian on one day may be as little as $24^h\ 39^m$, or as great as $25^h\ 5^m$. It never is quite so small as 38^m, or so great as 66^m over 24^h. Suppose the interval between two passages or transits of the meridian of Greenwich to be 40^m over 24^h. For a place 6^h west of Greenwich, one-fourth of the 40^m has already passed when the Moon arrives at this western meridian, and would pass it 10^m later in the day than it passed the meridian of Greenwich, even if the motion of the Moon should be uniform for the whole day. But it is not uniform,—the day before or the day after, it may be five or six minutes, more or less—usually the difference is not so great.

A second table is formed for the longitude of the place for which the almanac is made;—thus 24^h : long. of place :: interval at Greenwich : correction of transit at place. For Columbus, Ohio, it would be 24^h : $5^h\ 32^m$ :: 38.....: 9 : correction of transit at Columbus. This correction is added to the time of the Greenwich transit to find the transit for the given longitude. If the acceleration or retardation of the Moon's motion is rapid, allowance must be made for this variation, making the result of the above a little greater or a little less according to the variation. This is best shown by an example

For Antrim, Ohio, long. $5^h\ 25^m$ West.

	Moon South		Diff.
	h	m	m
1857, April 1,	6	38.1	
			.....55.3
" 2,	7	33.4	
			.....50.6
" 3,	8	24.0	
			.....46.3
" 4,	9	10.3	
			.....43.0
" 5,	9	53.3	
	:	:	::

Below are two examples worked out before the above date. Take April 3. The Moon is on the meridian at $8^h\ 24^m$; it must then set after midnight. We look in the Nautical Almanac for 1857, for midnight, April 3, and we find the Moon's declination is not far from 25° north : consequently the semi-diurnal arc will be large;—suppose it $7^h\ 30^m$—a mere guess.

Here is the work: Moon south $8^h\ 24^m$
Add semi-diurnal arc 7 30 to setting.

15 54 Greenwich apparent time of setting. From the Naut. Alm. we take the declination for this hour, and look in the table for the corresponding arc; it is

$7^h\ 11^m.6$
Add proportional part of 46.3^m 13 .8

$7^h\ 25^m.4$ corrected arc.
Moon on meridian $8^h\ 24^m$
Semi-diurnal arc 7 25.4 to setting.

15 49.4 Moon sets, but this is $3^h\ 49^m.4$ after midnight. Wherefore opposite April 4, is put $3^h\ 49^m$ morning. The refraction and semi diameter would make the time about 4 minutes later, but the Moon's parallax makes the time about 4 minutes earlier—so these corrections are allowed to offset each other.

April 4. Moon south $9^h\ 10^m.3$
Semi diurnal arc 7 4 .7 (guessed at the .7 put in to get integer minutes)

16 15 Apparent Greenwich time of setting.

For this hour the almanac gives the declination which corresponds to an arc if $6^h\ 52^m.4$ uncorrected for Moon's motion.
Correction for 43^m 12 .3 add

7 4 .7 true arc in time.
Moon on meridian 9 10 .3 add

16 15 .0 Moon sets at $4^h\ 15^m$ April 5.

A practised computer will seldom miss the arc more than 5^m. Should it be as much as 15, the resulting error would not be manifest in the result.

In this way the work is carried on till the Moon sets after daybreak; in general, when the Moon rises in the day time, the almanac gives the time of setting; when it sets in the day time, the almanac gives the time of rising.

In every month there is at least one day in which the Moon does not rise, or does not set, as the case may be. Suppose that on the 20th of some month the Moon sets at $11^h\ 30^m$ P. M., and that by the next night it has traveled 45^m further east, then it would set 15^m after 12, and this would not be the 21st, but the morning

of the 22d. In such a case, the word "morn." is written opposite the 21st and the $0^h\ 15^m$ opposite the 22d.

In this way the time of rising or of setting can be computed in two minutes or less, by one familiar with this process. I have frequently made all the computations for an almanac inside of one week, without neglecting any duty in college—having the while from 4 to 6 classes daily. The error in time will seldom be so much as one minute, and this is a quantity practically of no moment.

There is usually another column of miscellaneous things, sometimes as of old called "Aspects." This is usually made up of dates of note-worthy events, of the position of the planets, and of conjectures of the weather.

In an almanac on my table I find: "Oct. 1, ☿ Gr. E. long. E. 25° 44′; ☽ ☊; Oct. 11, ♂ ☌ ☉; Oct. 19, ♂ ♄ ☽; Oct. 31, ☐ ♃ ☉, etc., etc., taken from the Naut. Alm.

The weather predictions are usually to be relied on; one for October 1895 says in a long drawn out way covering the whole month: "Probably rain.....cool and clear.....rainy.....blustering.....more pleasant," and this will suit any October near the parallel of 40°.

Most persons who use almanacs believe that the Moon is the chief factor in changes of the weather; and that at the changes of the Moon the changes of the weather occur. If one will take the precaution to say, "on the day before or the day after," he will generally succeed half the time; for the three days implied constitute nearly half the time from change to change, and it would be strange if all the changes should always occur only on the other four or five days.

For many years I have seen what pretend to be Herschel's rules for changes of the weather, depending on the time of day when the Moon's change takes place. They are valueless and probably apocryphal. Other unfounded notions concerning the weather might be given but as they do not pertain to the making of almanacs they are passed by.

The only other points to be noticed are the chronological cycles usually given and the ecclesiastical festivals; but these may be disposed of in a brief note hereafter. Let the above suffice for the making of common almanacs.

Ball's Starland, by Sir Robert Ball, Astronomer Royal of Ireland, contains a series of most fascinating talks on popular astronomy for young people.

OBSERVATIONS FOR BEGINNERS. II.

WM. W. PAYNE.

In the September number of this publication we called attention to a method for naked-eye observations, in which any one sufficiently interested in a knowledge of the stars to give half hours to their study, on clear and moonless nights, might soon gain an acquaintance with the leading facts pertaining to them, that is not even very generally known to professional astronomers. Such knowledge ought to be anxiously sought by those who teach the elements of Astronomy, for nothing inspires young students more than that which they can see and do for themselves by easy and naturally graded steps of observation and investigation.

The student of the high school or the popular reader may undertake this work and succeed in it, if he will give time to it, and proceed methodically, and do thoroughly everything he tries.

The work that we suggested in the article above referred to was concerning the first magnitude stars then visible.

It was said that a table should be made in a note-book prepared for that purpose consisting of five columns. In the first column put the Arabic names of the stars, in the second the Greek letters designating them, in the third the name of the constellation to which they belong, in the fourth the color, and the fifth is intended for the observer's remarks. The first three columns can be filled easily, but the fourth is more difficult and will require careful observation and sometimes considerable study.

Those who followed our suggestions in the preceding article easily found five first magnitude stars, visible during the month of September in early evening. They were, by name, Altair of Aquila, Antares of Scorpio, Arcturus of Boötes, Capella of Auriga and Vega of Lyra. If our young observers were watchful they noticed that these stars were soon visible after sunset in strong twilight, and were clearly seen for some time before any other stars appeared. Antares was in the southwest near the horizon at nine o'clock, Altair and Vega near the meridian south of the zenith, Arcturus nearly west and Capella east of north, and a few degress above the horizon. Did the observer notice that the three A's and V make a quadrilateral figure, so that the places of all may be located from that of any one of the four ?

Antares is not now visible and Arcturus sets in early evening, but the other three can be well observed. About nine o'clock in the evening in the first part of this month three other first magnitude stars are visible above the eastern horizon. They are Aldebaran of Taurus and Betelgeuse and Rigel of Orion. These should be added to our first observing list.

We ought next to study the color of each of these stars, and it is best to begin with Vega and Altair because of their higher altitude. On this account their true colors will appear at best advantage. What is the color of Vega? Look at the star as soon as it appears in early evening with the naked eye, with an opera glass, field glass or small telescope. We have followed the star hours in the presence of full sunshine by the aid of a small telescope, so as to have the star shine from a blue back-ground for contrast, thereby avoiding some color arising from imperfectly corrected lenses of the telescope. On a perfectly clear and moonless night the sky is nearly black. Try Vega for color on such a night and see if the former opinion of its tint will hold. In a similar way the student should observe each of the other first magnitude stars. It is a good thing to try original devices if they give new and reasonable conditions, for such may help to form correct, independent judgment. For it should be a fact always in mind that the observer is advancing rapidly in knowledge and skill only as he forms *correct* and *independent judgment* for himself. In reference to the colors of these stars it will readily be seen that the color of Vega differs from that of Altair, and that Capella has a hue unlike either of them. Arcturus and Antares are more nearly alike. But such differences are not definite enough to classify color in the mind of many ordinary observers. While it is true that good observers do not agree in opinion as to the precise tints of all the first magnitude stars, it is also true that practiced normal eyes do not generally very widely differ in regard to the colors assigned to them.

Our list of first magnitude stars as extended for this month, then, will be as follows:

OBSERVING LIST I.

Name.	Gr. Letter.	Constellation.	Color.	Remarks.
Altair	α	Aquila	Bluish white	Standard 1st mag.
Antares	α	Scorpio.	Very red	
Arcturus	α	Boötes	Pale yellow	
Capella	α	Auriga	Yellowish white	
Vega	α	Lyra	Pale blue	
Aldebaran	α	Taurus	Reddish yellow	Standard 1st mag.
Betelgeuse	α	Orion	Orange red	
Rigel	β	Orion	Pale blue	Irregularly variable

There are only fourteen first magnitude stars north of 35° south declination if we accept Heis as authority.

It is not desirable to press this study of the color of the lucid stars too far, for astronomy has not yet laid a good foundation in principle by which this branch can be developed. Some acute eyes do marvellously in detecting very minute differences in tint, and the judgment of such observers have doubtless been accepted often too confidently by those of less experience.

For the sake of additional useful notes in regard to these stars, it may be well to compare them in respect to relative brightness. They are all called first magnitude stars. But it is easy to see

that they are not all equally bright. Altair is plainly less than Vega, but how does Vega compare with Capella? Is Arcturus brighter than Vega? The best answer that astronomy has for such questions is by the so-called photometric methods of measing star light intensity. Recent trustworthy results by this method give Altair and Aldebaran as strictly first magnitude stars, being just three times as bright as Polaris. Capella and Vega are rated as equal and both are eight-tenths brighter than Altair. Arcturus is two-tenths brighter than Capella, hence a whole magnitude brighter than Altair. Betelgeuse is inferior to the standard and Regel is variable.

These suggestions about color observations and relative brightness of this star list will give good exercise and ought to be practiced much.

Observing list number two will consist of about twenty-five second magnitude stars to be considered in the same general manner as list number one has been studied. If space permits it will be given this month for it contains some most wonderful stars that should be watched during this month. We believe that our star chart elsewhere given will be of special service in these elemental exercises.

THE SPECTRUM OF γ ARGUS.

L. A. EDDIE, F. R. A. S.

FOR POPULAR ASTRONOMY.

No mere description or illustration can adequately convey to the reader the sparkling splendour and superb beauty of the brilliant and variegated color band which this remarkable star yields when viewed even with the very simplest form of spectroscopic eyepiece upon a telescope of but small light gathering power such as that with which I for the first time had the privilege of examining this stellar wonder; viz., a McClean direct vision spectroscopic eyepiece on a 3-in. refractor, and subsequently on a 9¼-in. reflector.

Owing to the high southern latitude of this star (— 47° 2′) most astronomers in the North, who alone are armed with powerful spectroscopic apparatus, have been unable to examine for themselves this unique member of a type of stars which yield a continuous spectrum crossed with bright bands or lines and known as Wolf-Rayet stars.

γ Argus, a bright southern star of the 2nd magnitude, when viewed telescopically with a low power eye-piece is resolved into a group of four stars, three of which seem to be physically associated and are respectively of the 2nd, 6th and 8th magnitudes, the principal star of this triplet is white tinged with pale violet or cyan-blue; that of the 6th magnitude being greenish white, while the 8th magnitude comes shines with a purplish hue. In

the position angles of these companion stars considerable change would appear to have taken place since Herschel's early observations.

The bright banded nature of the spectrum of this star was first detected in 1871 by Respighi, at Madras, about four years subsequent to M. M. Wolf-Rayet's discovery of these faint stars in Cygnus showing bright lines superposed upon a continuous spectrum; and this star still occupies the isolated position, amongst these marvelous members of the heavenly host, of being the only conspicuous star which yields a spectrum of this compound type though some fifty-four minor members have now been catalogued; most of these latter have been discovered by the aid of photography, through the indefatigable labors of the eminent Professor Pickering of Harvard College Observatory, aided by the skillful assistance of Mrs. M. Fleming. Professor Pickering has also shown the remarkable fact that all these stars are situated near the central line of the Milky Way, a position which they seem to share in common with the planetary nebulæ, with which they may yet be discovered to be closely allied. The professor points out that all but six are within 6° of the Galactic equator and that only one is more than 9° distant from this line, three-fourths being within 3° thereof.

Mr. W. W. Campbell of the Lick Observatory, has made most complete calculations of the mean value of the wave-lengths of the bright and dark lines and bands in the compound spectra of all the stars of this type.

With the McClean spectroscopic eyepiece and a 9¼-inch mirror I have myself succeeded in detecting visually six bright lines in the spectrum of γ Argus, as shown in the diagram hereto annexed, viz: one faint in the reddish orange (5874), one very bright in the orange yellow (5813), one very bright in the greenish yellow (5694), one thin but fairly bright in the cyan-blue (4689), one very broad and bright of nearly the same tint (4651) also in the cyan-blue; and one very faint and narrow in the violet (4441); the last only seen when the atmosphere was exceptionally clear. The greenish yellow band (5694) appears to me slightly broader than the orange yellow band (5813) and the interval between these bands which appears greyish by contrast, is about one and one-half breadths of the greenish yellow band; the faint reddish orange band (5874) is about three-fourths of the thickness of the orange yellow band (5813) The broad blue band (4657) appears to be very sharply defined on its more refrangible border and somewhat gradually toned off on its less refrangible edge; the blue line (4689) is very thin but bright.

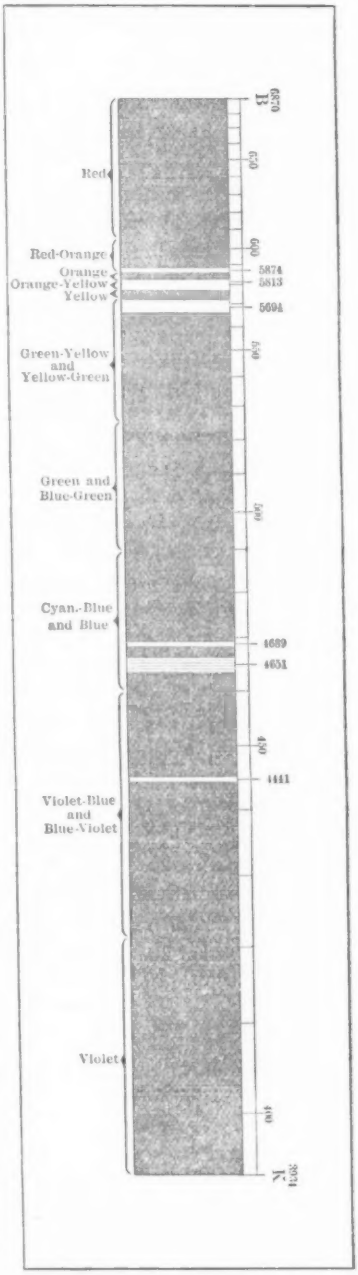
Though with the limited optical aid at my disposal I have been able to see only 6 bright lines in the spectrum of γ Argus, as described above, Professor Campbell, with the aid of the magnificient spectroscope attached to the mighty Lick telescope has been enabled to detect and accurately determine the positions of ten bright lines and bands by visual observations, while investigations of the photographic portion of this spectrum carried on by him at Mt. Hamilton have revealed many additional bright lines as well as some dark lines.

The following are the mean wave lengths of the bright lines deduced from the results of Mr. Campbell's various investigations.

Visual lines: 672, 6565, 5874, 5813, 5694, 5596, 5411, 4689, 4651, 4441.

Photographic lines: (exposure on ordinary dry plates.) 4787, 4688, 4651, 454, 4517, 4504, 4480, 4467, 4442, 432, 4270, 4227, also dark lines Hγ, Hδ, Hε.

Photographic lines: (exposures on isochromatic plates). All the visual bright lines (except Hα) and 5470, 5185, 5020, 494, 4787. Also dark line 4473, probably the chromospheric line 4472. In this star therefore for the first time is observed the remarkable phenomenon of the same gas yielding dark and bright lines simultaneously, the Hα line revealing itself as bright while the other H lines are recorded as



dark. The continuous spectrum extends from B to K and the blue and violet portions are extensive and brilliant thus lending that soft violet white light with which this star shines in our southern skies. The red is of a very rich hue while the orange and yellow are confined to a very limited space.

Professor Lockyer in his Meteoric Hypothesis differs greatly from Campbell in the estimated wave lengths of the principal lines adopted by him; these are as follows: 590, 580.9, 5661.8, 468, and endeavors to identify the blue band with carbon and the yellow with sodium.

While Copeland, again, gives 590 (faint) 5809, 5668, 4646 (strong and intensely bright) as the measure of the wave lengths of the bright lines observed by him at Pano, Peru; and Ellery recorded 5760, 5648 and 4682 as the wave lengths of bright lines seen by him at Melbourne. But Professor Campbell's very recent measures are likely to prove more reliable, being effected by the most modern instrumental aid of the highest class, and through one of the most competent observers, well versed in all the advanced knowledge pertaining to this class of investigation.

Various theories have been propounded to account for this wonderful compound spectrum of a triple nature, comprising a continuous spectrum, an absorption spectrum and an emission spectrum.

Professor Campbell suggests that the bright lines are probably chromospheric, owing their origin to a very extensive and highly heated atmosphere; but showing very little relation, in constitution and physical condition, to that of our own Sun. "For the present, at least," he adds, "this type of spectrum is distinct and like the nebular spectrum containing lines whose origin cannot now be assigned."

Dr. Scheiner offers the hypothesis that the spectrum is made of three components but all from the same body; the first, a continuous spectrum, due to an incandescent photosphere; the second, an absorption spectrum, produced as in other stars, by an atmosphere of lower temperature than the photosphere; the third, an emission (bright line) spectrum, owes its origin to an enormous gaseous envelope of unknown composition surrounding the absorbing atmosphere and producing a bright line spectrum by supplying to the slit of the spectroscope a greater quantity of light than the star's photosphere, in spite of the higher temperature of the photosphere. This theory seems to be borne out by Campbell's recent observations on another star of this type, viz: D. M. + 30°.3639 which he observed spectroscopically

to be surrounded by an extensive outer envelope of incandescent hydrogen yielding with a narrow slit, focused on the F line, a long and extended line on either side of the continuous spectrum, and with an open slit, a large circular disc about 5″ in diameter.

Professor Lockyer's theory is in some respects similar to Dr. Scheiner's, as far as the relative temperatures of the chromosphere and outer envelope producing the bright lines are concerned; but as to the composition of this envelope he assumes that these bright lines are due to low temperature sodium and iron, and to carbon flutings on a bright continuous spectrum.

E. B. Frost, M. A., in his very valuable English translation of Dr. Scheiner's most elaborate work, "Die Spectralanalyse der Gestirne," says that the explanation of the spectrum of any of this class of star might be simplified if it were possible to consider that the spectrum is a compound one, due to the superposition of the spectra of two adjacent and physically connected bodies, as seems to be the case with β Lyræ and with certain temporary stars. "The observations thus far available," he states, "do not, however, properly admit of such an interpretation."

No variability has as yet been detected in any of the stars of this type, nor has any change whatever been noted in any of their bright lines.

Professor Pickering's late observations, made at Peru, have confirmed the fact that the above ultra-violet lines in γ Argus, α to δ, are dark.

Though great advance has recently been made in the investigations of the physical condition of this beautiful sidereal wonder, together with others of this type, the data as yet collected are far too incomplete to deduce therefrom any well-founded theory of its physical constitution, or to afford a probable history of its past and present condition; but a close study by competent physicists with the command of the most modern optical aid, will, I am sure, yield valuable and highly interesting facts that may lead to a satisfactory explanation of the complex nature of this unique member of the heavenly hosts which may indeed be styled *the spectral gem of the southern skies*.

GRAHAMSTOWN, South Africa,
Aug. 8, 1895.

ON THE NEWTONIAN CONSTANT OF GRAVITATION.*

I.

It is probably within the knowledge of most of those present that Sir Isaac Newton, by his great discovery of gravitation and its laws, was able to show that a single principle, ideally simple, viz: that every particle of the universe attracts any other particle towards itself with a force which is proportional to the product of their masses divided by the square of the distance between them, would completely and absolutely account for the three laws of planetary motion which Kepler had given to the world.

Newton also showed that a spherical body, whether uniformly dense or varying in density according to any law from the center to the surface, would attract bodies outside with the same force that it would do if it could all be concentrated at its centre, *i. e.*, that all the attractions varying in amount and direction produced by particles in all parts of a sphere need not be considered, separately, but may be treated in this simple way.†

Nevertheless, though Newton's great discovery is sufficient to bring the whole of the movements of the planets and their satellites, whether their simple Keplerian motions or the disturbances produced by their mutual gravitation, the motions of comets, of binary stars, of the tides, or the falling apple, under the domain of a single and simple principle, though it enables one to compare the masses of the Sun, the planets and their satellites, and of those binary stars whose parallax has been determined, one thing can never be made known by astronomical research alone, though we may know that twenty-eight suns would be required to make one Sirius; that the Sun is equal to 1048 Jupiters, that Jupiter is more than double all the rest of the solar system put together, or that the Moon is 1/80 of the Earth; no observations of these bodies can ever tell us how many tons of matter go to make up any one of them.

Though we know from first principles of dynamics, by the mere consideration of centrifugal force, that the whole Sun attracts each ton of the Earth with a force equal to a weight here of a little more than one pound, and that if it were not for this, every ton of the Earth would continue its journey into space in a straight line for ever, and though we know in the same way that

* A lecture delivered at the Royal Institution on June 8, by Professor C. V. Boys, F. R. S.

† Only last night I learned that it was the difficulty of proving this, and not the erroneous value of the Moon's distance, that delayed the publication of Newton's discovery for so long.

the whole Earth attracts each ton in the Moon with a force equal to the weight of ten ounces and no more, we cannot tell by any astronomical observation whatever, how many tons there are in all.

Newton showed that to complete his law and to put in the numerical constant (the Newtonian Constant of Gravitation) that would convert his proportion into an equality, two methods are available: we may either make observations on the disturbance of the Earth's gravitation by the action of isolated parts of it, we may either find the relative attraction of an isolated mountain or the strata above the bottom of a deep mine, or we may make an artificial planet of our own and find the attraction which it exerts.

The Newtonian Constant will be known if we know the force of attraction between two bodies which we can completely measure and weigh. Employing the C. G. S. system of measurement, the Newtonian Constant is equal to the force of attraction in dynes between two balls weighing a gramme each, with their centres one centimetre apart. Of course it may be referred to pounds and inches or tons and yards, but as soon as all the quantities but G in Newton's equation

$$\text{Force} = G\,\frac{\text{Mass} \times \text{Mass}}{\text{distance}^2}$$

are known, no matter in what units the quantities are measured, G is known. The conversion of its numerical value from one system of measurment to another is of course a mere matter of arithmetic.

Of the first method of finding G, depending on the attraction of a mountain first attempted by Bouguer at the risk of his life in the hurricanes of snow on Chimborazo, of the experiments of Maskelyne, of Airy and of others, I cannot now find time to speak; I can only refer to Poyonting's essay on the subject. It is the second method with an artificial planet that I have to describe to-night.

Now let me give some idea of the minuteness of the effect that has to be measured. Is a wall built true by the aid of a plumb-line verticle, or does it lean outwards? Newton's principle shows that the plumb-bob is attracted by the wall, yet it hangs vertically. The attraction is so small that it cannot be detected in this way. Even the attraction of a whole mountain requires the most refined apparatus to detect it. Do two marbles lying on a level table rush together? According to Newton's principle they

attract one another; yet if they were a thousand times smoother than they are, no movement of attraction could be detected.

Leaving matters of common experience, let us go into the physical laboratory where instruments of the highest degree of precision and delicacy (at least so they are called) are found on every table. What precautions are taken to prevent the attractions of the fixed and moving parts from interferring with the result which they are constructed to measure? None. The attractions are so small, that in no apparatus in use for the measurement of electrical, magnetic, thermal, or other constants are they ever thought of, or is any provision necessary to prevent their falsifying the result. Nevertheless, the attractions exist, and if only the means are delicate enough they can be detected and measured. The Rev. John Mitchell was the first to devise a successful method. He was the first to invent the torsion balance with which Coulomb made his famous electrical researches, and which bears Coulomb's name. He devised and he made apparatus for this purpose, but he did not live to make any experiments.

After his death Cavendish remodelled Mitchell's apparatus and performed the famous Cavendish experiment. By means of the appartus, of which for the second time I show a full-size model in this theatre, Cavendish measured the force of attraction between two balls of lead, one 12 and the other 2 inches in diameter, and with their centres 8.85 inches apart. The same experiment has since been made by Reich, by Baily, and more recently by Cornu and Baille with greatly superior apparatus of one quarter of the size. All these observers actually determined the attraction between masses which could be weighed and measured, and thus found with different degrees of accuracy the value of G.

Let me explain now that this G, the gravitation constant, or as I prefer to call it, for the sake of distinction, the Newtonian Constant of Gravitation, has nothing to do with that other quantity generally written g, which represents the attraction at the Earth's surface. This is a purely accidental quantity, which depends not only upon G, but also upon the size of the Earth, its mean density, the latitude, the height above the sea, and finally upon the configuration and the composition of the neighboring districts. g is eminently of a practical and useful character; it is the delight of the engineer and the practical man; it is not constant, but that he does not mind. It is of the Earth, arbitrary, incidental and vexatious. Professor Greenhill should spell his

name with a little *g*. G, on the other hand, represents that mighty principle under the influence of which every star, planet and satellite in the universe pursues its allotted course; it may possibly also be the mainspring of chemical action. Unlike any other known physical influence, it is independent of medium, it knows no refraction, it cannot cast a shadow. It is a mysterious power, which no man can explain; of its propagation through space, all men are ignorant. It is in no way dependent on the accidental size or shape of the Earth; if the solar system ceased to exist it would remain unchanged. I cannot contemplate this mystery, at which we ignorantly wonder, without thinking of the altar on Mars' hill. When will a St. Paul arise able to declare it unto us? Or is gravitation, like life, a mystery that can never be solved?

Owing to the universal character of the constant G, it seems to me to be descending from the sublime to the ridiculous to describe the object of this experiment at finding the mass of the Earth, or the mean density of the Earth, or, less accurately, the weight of the Earth. I could not lecture under the title that has always been chosen in connection with this investigation. In spite of the courteously expressed desire of your distinguished and energetic secretary, that I should indicate in the title that, to put it vulgarly, I had been weighing the Earth, I could not introduce as the object of my work anything so casual as an accidental property of an insignificant planet. To the physicist this would be equivalent to leaving some great international conference to attend to the affairs of a county council, I might even say of a parish council. That is the business of the geologist. The object of these investigations is to find the value of G. The Earth has no more to do with the investigation than the table has upon which the apparatus is supported. It does interfere and occasionally, by its attraction, breaks even the quartz fibers that I have used. The investigation could be carried on far more precisely and accurately on the Moon, or on a minor planet, such as Juno; but as yet no means are available for getting there.—*Nature, Vol. 50, No. 1292.* (*To be Continued.*)

THE ADJUSTMENT OF A SMALL EQUATORIAL.

H. A. HOWE.

First Article.

For Popular Astronomy.

In these articles will be given simple methods of adjusting a small equatorial properly in the meridian. The directions for ad-

justment will be made exceedingly explicit. To avoid the possibility of any misunderstanding the following preliminary explanations are made.

The declination axis is the one which is perpendicular to the telescope tube, near its center. The polar axis is, in most instruments, shorter than the declination axis, and is perpendicular to it. When the instrument is properly adjusted the polar axis is parallel to the rotation axis of the Earth, and points toward the north celestial pole. For any instrument of reputable make we may assume, for our present purposes, that a line connecting the center of the object-glass with the center of the eye-piece (which we shall call the sight-line) is the geometrical axis of the cylindrical surface of the telescope tube, and is perpendicular to the declination axis. We similarly assume that the declination axis is truly perpendicular to the polar axis.

I. Adjustment of a Portable Equatorial.

When a portable equatorial, which is usually mounted on a tripod stand, is taken out for an evening, it is best to set it up in such a position that the polar axis points nearly to the north celestial pole. For then any object under observation may be kept in view by rotating the instrument about the polar axis alone, rather than about both axes.

On a line between Gamma Cassiopeiæ and Polaris, and only three degrees from the latter lies the fourth magnitude star 43 Hev. Cephei. A line drawn from this star to Polaris, and prolonged one degree and a quarter, terminates close by the pole. To direct the polar axis to this point first place the telescope so that the sight-line is parallel to the polar axis. This parallelism can probably be most accurately obtained by placing the telescope vertically above the polar axis. Having then clamped both the axes set the tripod in such a position that the telescope points to the celestial pole. The axes may then be unclamped, but the position of the tripod must not be changed. When much observing is to be done it is best to have a post on which the instrument, robbed of its tripod legs, may be set.

When a portable instrument has one vertical axis and another horizontal one, it is frequently easy to fasten it to a post in such a way that the former vertical axis will point toward the north celestial pole.

II. Adjustment of a Small Equatorial, Without Graduated Circles, Mounted on a Fixed Pillar.

1. *General Remarks.* The instrument is made in such a way

that the inclination of the polar axis to the horizon can be altered. This inclination should be equal to the latitude of the place of observation, which is supposed to be known. But if the polar axis has the right inclination to the horizon it may point either to the right or to the left of the celestial pole. The framework holding the polar axis (called the headstock) should therefore be capable of rotation in a horizontal plane about an imaginary vertical axis. Some makers provide screws for turning the headstock horizontally, while the pillar below it remains fixed. Others bolt the headstock to the upper section of the pillar, and furnish screws for turning the upper section of the pillar upon the lower section. In either case this horizontal movement is called *the adjustment for azimuth*. In mounting the instrument care must be taken to set the pillar vertical. This is most readily accomplished by setting the lowest section of the pillar so that its upper surface is horizontal; a good carpenter's level, carefully used, will suffice for this work. The level may first be set on the pillar, the level-tube pointing north and south; it may then be lifted up, turned so that the former north end is now south, and set down again. If the bubble is in the middle of the tube each time, a similar set of observations may be made with the level pointing east and west. In case the bubble still remains in the center of the tube the pillar is properly leveled.

2. *Latitude adjustment of the polar axis.* In order to incline the polar axis at the proper angle with the horizon construct a wooden right triangle one of whose angles is equal to the latitude of the place. This may be made of three pieces, each an inch thick and two or three inches wide. Place the telescope directly over and parallel to the polar axis, with the object-glass north of the eyepiece, the declination axis lying in the same vertical plane as the polar axis; clamp both axes. Set the wooden triangle so that its hypotenuse rests on top of the telescope tube, and is parallel to the sight line, that acute angle of the triangle which equals the latitude being north of the right angle. If the uppermost side of the triangle is not horizontal make it approximately so, by changing the inclination of the polar axis to the horizon. Test the horizontality of this side of the triangle by placing the carpenter's level on top of it, and change the inclination of the polar axis again, if necessary, until the bubble is in the center of the level tube. Turn the level end for end and see if the bubble still stands in the middle of its tube.

In order to reach a good degree of assurance, unclamp both axes, and change the position of the declination axis. Then place

the telescope tube directly over and parallel to the polar axis, with the object glass south of the eyepiece, the declination axis being again put into the same vertical plane as the polar axis. Use the wooden triangle and level as before. If the level bubble does not now stand very close to the center of its tube, either the work has been carelessly done, or the declination axis deviates perceptibly from perpendicularity to the tube of the telescope.

3. *First Method of Making the Azimuth Adjustment of the Polar Axis.* The declination axis is first to be made horizontal. If the instrument is so constructed that this cannot be done well by placing the carpenter's level on top of the declination axes, we may proceed as follows: Point the telescope straight upward, having it on the east side of the pillar. Place the level against the south (or north) side of the tube and turn the telescope until the bubble of the cross-level is in the middle of its tube. Theu place the level in contact with the east side of the tube, and move the tube again till the bubble stands in the middle of its run. Try the level on the south side of the telescope-tube again. By a few successive trials on the south and east sides of the tube, the telescope may be made vertical. Since the declination axis is supposed to be perpendicular to the tube of the telescope, it will be horizontal, when the latter is vertical.

Having made the declination axis horizontal in either one of the preceding ways clamp the polar axis firmly; test the horizontality of the declination axis, to see whether it was disturbed by clamping the polar axis. If no disturbance has taken place, rotate the telescope carefully about the declination axis, till it points nearly to the north celestial pole, and make use of Polaris in the manner described below. The times when Polaris is on the meridian during the year 1896 may be obtained with sufficient accuracy from the following table. The times of both culminations are given, so that the observer may choose that one which is the more convenient. In case neither culmination comes at a convenient hour, Delta Ursæ Minoris may be used instead of Polaris. The time of culmination of either star for a date not given in the table may be found by multiplying the number of days between the required date and the next preceding date in the table by 3.93 minutes, and subtracting the product from the time given opposite the date in the table. For instance let Aug. 13 be the date for which the time when one of these stars is on the meridian is desired. A glance at the table shows that Polaris is at upper culmination about 3:30 A. M., and at lower culmination about 3:30 P. M. As both these times are incon-

venient we turn to Delta Ursæ Minoris which is at once seen to be at upper culmination about 8:30 P. M. The next preceding date in the table is Aug. 1, and the time of upper culmination on that date is $9^h\ 21^m.1$ P. M. The number of days between Aug. 1 and Aug. 13 is 12. $12 \times 3^m.93 = 47^m.2$. $9^h\ 21^m.1 - 47^m.2 = 8^h\ 33^m.9$, which is the time desired.

A few minutes before the time of culmination the observer should take his place at the telescope, the lowest power having been put on previously, and properly focused. Rotate the telescope carefully about the declination axis, leaving the polar axis firmly clamped, until the star comes into the field of view. If it cannot be found in this way sight along the tube at it (as if sighting a gun) and turn the headstock in azimuth till the star is put nearly in the center of the field of view. Have the star in the center of the field of view at the computed time of its culmination: the headstock will then need no further movement, and the adjustment of the polar axis may be considered complete.

	Polaris.				Delta Urs.æ Minoris.			
	Upper Culmination.		Lower Culmination.		Upper Culmination.		Lower Culmination.	
	h	m	h	m	h	m	h	m
Jan. 1	6	36.2 P. M.	6	38.2 A. M.	11	22.1 A. M.	11	20.0 P. M.
Feb. 1	4	33.9 P. M.	4	35.8 A. M.	9	20.3 A. M.	9	18.3 P. M.
Mar. 1	2	39.5 P. M.	2	41.4 A. M.	7	26.4 A. M.	7	24.4 P. M.
Apr. 1	12	37.4 P. M.	12	39.4 A. M.	5	24.7 A. M.	5	22.7 P. M.
May 1	10	39.6 A. M.	10	37.6 P. M.	3	26.9 A. M.	3	24.9 P. M.
June 1	8	38.0 A. M.	8	36.1 P. M.	1	25.0 A. M.	1	23.1 P. M.
July 1	6	40.5 A. M.	6	38.6 P. M.	11	23.1 P. M.	11	25.1 A. M.
Aug. 1	4	39.2 A. M.	4	37.2 P. M.	9	21.1 P. M.	9	23.1 A. M.
Sept. 1	2	37.7 A. M.	2	35.8 P. M.	7	19.1 P. M.	7	21.0 A. M.
Oct. 1	12	40.0 A. M.	12	38.1 P. M.	5	20.9 P. M.	5	22.9 A. M.
Nov. 1	10	34.2 P. M.	10	36.2 A. M.	3	18.8 P. M.	3	20.8 A. M.
Dec. 1	8	36.1 P. M.	8	38.0 A. M.	1	20.7 P. M.	1	22.7 A. M.

4. *Second method of making the azimuth adjustment of the the polar axis.*—It is a good plan when building an Observatory to make on the floor of the dome room a north and south line running through the center of the room, and also an east and west line running a few inches north of the center of the room, so as not to encounter the pillar. These lines may be established by the use of an engineer's transit, which may be put in the meridian by solar observations, or by an observation of Polaris. The north and south line will be useful in setting the lowest section of the pillar correctly.

The east and west line may be employed as follows for making the azimuth adjustment of the polar axis. Make the declination

axis horizontal in either one of the ways described above under the First Method, the telescope being on the east side of pillar. With the aid of a planet locate on the floor the point which is vertically below the west end of the declination axis. Reverse the telescope so that it is on the west side of the pillar, and by means of the plumb locate on the floor the point which is vertically under the east end of the declination axis. If these two points are not equidistant from, and on the same side of the east and west line drawn on the floor, move the headstock in azimuth until they are.

Instead of plumbing down from the extremity of the declination axis one may, after making that axis horizontal, make the telescope also horizontal, and mark on the floor, with the end of the plumb, the point vertically under the "peep-hole" of the eyepiece. The telescope may then be rotated 180° on the declination axis, and another point be located on the floor vertically under the new position of the "peep-hole." The line joining these two points should run north and south.

It is, however, perhaps better to plumb down from the end of the declination axis (as above directed) than from the eyepiece, since an error arising from a possible lack of perpendicularity of the polar to the declination axis is thereby avoided.

In the next article will be considered the adjustment of an equatorial which has graduated hour and declination circles.

AN IMPORTANT METHOD OF SOLVING KEPLER'S EQUATION.

F. R. MOULTON.

For Popular Astronomy.

The equation connecting the mean and eccentric anomalies, in an elliptic orbit whose elements are known, has always been a source of much labor to astronomers. This equation was discovered by Kepler and bears his name. Several hundred solutions have been invented for it by mathematicians during the last two hundred fifty years, but not one of these has been found practicable for ellipses of all eccentricities.

The graphical method which we shall now describe is not only applicable to ellipses of all eccentricities, but gives the solutions with the greatest facility.

For the benefit of readers who may not have worked much in orbits we shall enter somewhat into the details of the problem.

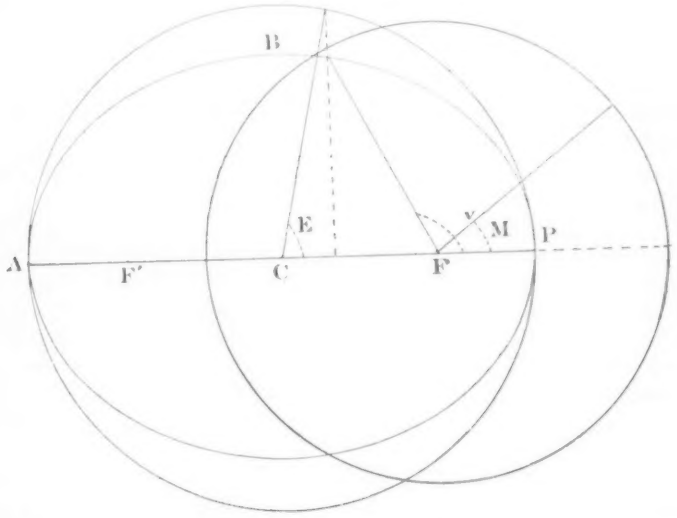
When we know the period of one body revolving about another, as a planet around the Sun, we know at once its mean angular motion. Representing this by n it is given by the formula

$$n = \frac{360^\circ}{P}$$

in which P is the planet's period. We now suppose that some fictitious body moves uniformly around the Sun with this mean angular motion n, and then at any time t, its angular distance from the perihelion will be $(t - T)\, n$ where T is the time of perihelion passage. This is the mean anomaly at that epoch and is denoted by M. The true anomaly is the angle actually passed over by the planet's radius vector and is denoted by v. The geometrical representation of the eccentric anomaly is the angle between the major axis and a line drawn from the center of the ellipse to the point where an ordinate drawn through the true place of the planet intersects the auxiliary circle. This is shown in the figure and is denoted by E.

In the figure PBA represents the elliptical orbit of the planet; F, the focus and place of the Sun; C, the center of the ellipse; P, the perihelion point; M, the mean anamoly; v, the true anomaly and E, the eccentric anomaly.

Fig 1



In order to determine the true place of the planet at any epoch

we first calculate the eccentric anomaly from the mean anomaly and then the true anomaly by the formula

$$\tan \tfrac{1}{2}v = \sqrt{\frac{1+e}{1-e}} \tan \tfrac{1}{2}E. \qquad (1)$$

where e is the eccentricity. The equation expressing the relation between the mean and eccentric anomalies is given in all works on Theoretical Astronomy and has the well known form

$$M = E - e \sin E. \qquad (2)$$

This is a transcendental equation and cannot be solved directly for E, which is the quantity desired. When, however, the eccentricity is small the value of E may be expanded into a converging series by Lagrange's Theorem and has the form

$$E_0 = \left\{ M + e'' \sin M + e'' \left(\frac{e}{2}\right) \sin 2M + \ldots . \right\} \qquad (3)$$

From a few terms we calculate E_0, which is an approximate value of E, and then from formula (2) we calculate M_0. We are then able to get a more correct value of E by the following formula:

$$E = E_0 + \frac{M - M_0}{1 - e \cos E_0} \qquad (4)$$

A repetition of this process two or three times will give a very satisfactory value of E when the eccentricity is small; when it is large the series fails to converge with the desired rapidity and recourse must be had to such tables as are given in Gauss' *Theoria Motus*, Oppolzer's *Bohnbestimmung* and Watson's *Theoretical Astronomy*. When the eccentricity is neither very small nor very large the solution is more laborious still. The practical difficulties are such in this last case that Laplace was led to say in the Mécanique Céleste that it is a fortunate circumstance that the eccentricities of the orbits of the heavenly bodies are all either very large or very small. In any case the determination of a large number of true places of a body in its orbit requires a great amount of work; but when the eccentricity has a medium value as is the case with the orbits of binary stars, the asteroids and some of the periodic comets the solutions are extremely tedious. In these cases the graphical method can be used to the greatest advantage.

This important method was originally proposed by Dubois* and was afterwards mentioned in Klinkerfues' "Theoretische Astronomie," but seems never to have come into general use

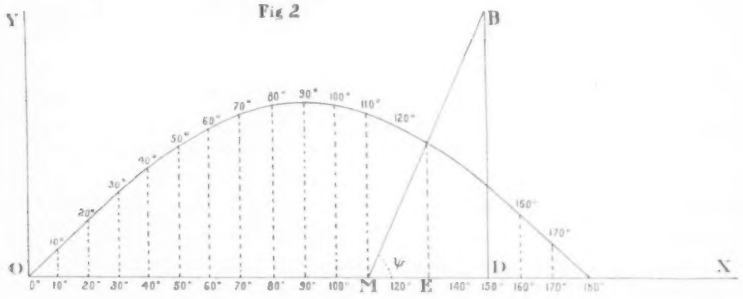
* *Astronomische Nachrichten* No. 1404.

among astronomers. Dr. T. J. J. See* has recently brought it to light again and by a slight modification has rendered it of the highest importance as a labor saving device. Without this advantage in calculation it would be almost impossible to carry out such an immense work as that involved in his revision of the the double star orbits, which requires us to compute the positions of the bodies for a great number of epochs.

The solution is as follows: We first construct on a convenient scale, one branch of a curve of sines, $y = \sin x$.

In practice it will be found convenient to draw it upon millimetre paper. We take the beginning of the arc as the origin of the co-ordinates and mark down the number of the degrees on both the curve and the axis of x.

Fig 2



Now in the figure let OM be the mean anomaly; then draw a line from M making an angle ψ with the axis of x, ψ being determined by the equation

$$\tan \psi = \frac{1}{e} \qquad (5)$$

then the reading of the arc upon the sine curve where it is intersected by the line is the eccentric anomaly corresponding to the mean anomaly OM, in an orbit whose eccentricity is e. This is shown to be true as follows: Since $\tan \psi = \frac{1}{e}$

$$MA\ e \sin \psi = MA \cos \psi \qquad (6)$$

and we see from the figure that

$$MA \cos \psi = ME \qquad (7)$$

Since our curve is a sine curve we have also

$$AE = MA \sin \psi = \sin E \qquad (8)$$

* *Monthly Notices*, June 1895.

Therefore from (6), (7) and (8) we have

$$e \sin E = ME \tag{9}$$

But

$$OE - ME = OM \tag{10}$$

therefore

$$M = E - e \sin E \tag{11}$$

which is Kepler's Equation.

In practice, therefore, we carefully construct a sine curve and mount it upon a light board where it can be preserved. We then cut out a triangle ($M\ B\ D$ in the figure) from cardboard or heavy paper, having an acute angle ψ determined by the eccentricity, according to formula (5). Since the eccentricity for any orbit is constant this triangle can be used, as Dr. See first pointed out, for all solutions of that orbit by merely keeping its base upon the axis of x and sliding it along until the vertex falls upon the points corresponding to the mean anomalies, when the eccentric anomalies can be read off at the top where the hypothenuse of the triangle intersects the curve. By numbering from 180° up to 360° in going back to the origin we are enabled to read off directly the solution of Kepler's equation for any mean anomaly whatever. When a new orbit with a different eccentricity is taken it is only necessary to cut out a new triangle with the proper angle ψ.

Since the sine curve is constructed from a transcendental equation it can only be made by plotting points tolerably close together, and then drawing a smooth curve through them by hand, hence it will be subject to some slight inaccuracies. However, it has been found in practice that the solutions can be read off directly, accurate to within one-tenth of a degree, which is quite sufficient for most of the work on binary stars at the present time. One hundred of these solutions can be obtained in half an hour, while by the ordinary methods a skilled computer could not arrive at the same results in less than a day. This gain is especially great when e is neither very large nor very small. This method of solution will generally give more accurate results than the first approximation obtained by the series; but, if greater accuracy is required the values first found may be readily corrected by formula (4) as in other cases.

Thus it appears that whether we desire a close approximation or greater accuracy, the graphical method of solving Kepler's Equation offers a decided advantage over all methods of compu-

tation. Professional astronomers should not be slow to adopt methods which will lighten their labors, thus leaving them more time to devote to the theories of their sublime science, and amateurs should welcome every method that will enable them to enter fields which have hitherto been too much reserved to the few. The description of the sine curve and triangle device above given will enable any one to construct his own apparatus and do valuable work in orbits, without the use of long formulæ which we believe have deterred many from entering upon work which might have been of great value to science.

UNIVERSITY OF CHICAGO,
Oct. 4, 1895.

THE SPECTROSCOPE IN ASTRONOMY.

TAYLOR REED.

FOR POPULAR ASTRONOMY.

To our knowledge of the solar system the spectroscope makes various interesting, if no vital, contributions.

In the case of the Moon the character of the radiation is detected. This may be understood by considering that the spectroscope spreads out the light we see so that it may be examined part by part; and further, it no less spreads out the light we can't see, below the red and above the violet, so that this too may be examined in detail; though these 'invisible radiations' must be studied by other apparatus substituted for the human eye. In the Moon's light the invisible radiations beyond the red are unduly intense compared with the visible part of the spectrum. Since this indicates a source at lower temperature we are led to suppose that only a part of the light received from the Sun by the Moon is reflected; and that much of it is first absorbed at the Moon's surface, and then given out by radiation. (a good terrestrial analogy is the ordinary fireplace, where most of the radiation is invisible, from the heated bricks).

For Mercury, Venus and Mars, the spectroscope seems to indicate an atmosphere, and an atmosphere of the same character as the Earth's. The course of the light from any of them is from the Sun to the planet, into its atmosphere a certain depth (an unknown depth; to the planet's surface?) back out of the planet's atmosphere, thence to the Earth and through the Earth's atmosphere to us. This light may be compared with light coming directly from the Sun through our atmosphere to

us; or, more conveniently, with light coming from the Sun to the Moon (which has no atmosphere), thence through the Earth's atmosphere to us. The difference in course between the light from the planet and light from the Moon is double passage through part (or the whole) of the planet's atmosphere. Now in the spectrum of the Sun as we see it certain effects are known to be due to the Earth's atmosphere. In the light from Mercury, Venus or Mars, these effects are found by observation to be slightly intensified, while the spectrum is otherwise unchanged. This shows that the effect of the atmosphere of any of these planets is the same in kind as the effect of the Earth's atmosphere; that the character of the atmosphere at least is the same, though the density may be different.

In the case of Mars this matter of atmosphere is interesting as bearing on the question of the presence of life. Even without the spectroscope it seems certain that Mars has an atmosphere of some kind; but it is an advance to know that it contains, like our own, water vapor; water vapor, involving probably water or ice on the surface; water vapor, from which possibly the polar snow-caps are supplied. However, within the last few months the correctness of spectroscopic evidence of any atmosphere at all on Mars has been hotly questioned; at present the whole matter promises a pretty battle.

The spectra of the major planets are peculiar; but interesting only to the professional spectroscopist. The most interesting and surprising fact is that the spectra of Jupiter's satellites seem to be identical with that of Jupiter; as if the satellites were in the same unhardened state as Jupiter himself.

A comet gives a spectrum of three bright bands superposed on a fainter continuous spectrum. An identical spectrum is produced by the base of a Bunsen burner. In some few bright comets, traces of one or two other bands are found. It would seem that there exists in comets some compound of hydrogen and carbon. In a few comets, when near the Sun, metallic lines have been occasionally seen: sodium notably, and less certainly iron. It should be noted, too, that some few comets, as Holmes' comet of a couple of years ago, give a continuous spectrum; that is, probably, a solar spectrum, of light reflected from the Sun: continuous apparently, since the light is too faint for detection of solar lines.

The bearing of the banded spectrum of the average comet on the constitution of the comet has been a subject of much speculation; some of this speculation founded on supplementary experi-

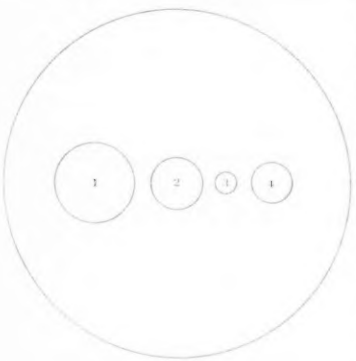
ment, some of it pure guess work, founded on nothing. Some hold that the light is the effect of collisions. Others maintain that it is produced by electrical discharge among the parts of the comet. And there seems to be some ground for thinking that the spectrum, of hydro-carbon chiefly, is modified by carbon monoxide.

FOUR LITTLE SKY TRAVELERS.

E. E. BARNARD.

FROM SAN FRANCISCO EXAMINER.

Between the orbits of the planets Mars and Jupiter is situated a zone of very small planets. At least 400 of these little bodies are now known, and they doubtless exist by thousands. How small the smallest of these may be cannot be even estimated. Possibly there may be multitudes of them not larger than grains of sand; but such, of course, we can never see. The smallest that have been discovered are possibly not above ten miles in diameter. The first four discovered of these bodies, however, are of considerable dimensions, and form respectable but modest-sized worlds. The first one of these objects known was discovered January 1, 1801, by Piazzi of Palermo in Sicily. He named it Ceres after the tutelary goddess of Sicily. It was found to be revolving around the Sun in a period of four and sixth-tenths years at a mean distance of 256 millions of miles. A second, third and fourth were found in the years 1802, 1804 and 1807, respectively, by Olbers and Harding, the former discovering two. These were named Pallas, Juno and Vesta. It was suggested by Olbers that possibly these were hot fragments of a great planet once existing between Mars and Jupiter that had for some unknown reason burst asunder. A further and immediate search did not reveal any more of the "fragments."



RELATIVE SIZE OF ASTEROIDS AND MOON. The Including Circle Represents the Moon.

Nearly forty years afterward, however, Hencke, after a long search of many years, began anew the discovery of these small

planets in 1845, since which time their discovery has been rapid, Especially has the discovery increased enormously in the past three years through the agency of photography. What their origin is due to we do not know. It is not probable, however, that they are the results of the burstings of any one planet, as suggested originally by Olbers.

These bodies have been variously called asteroids—minor planets. They are so small that in ordinary telescopes they appear only as stellar points, without any sensible or measurable disks. Various efforts have been made to determine the dimensions of the brighter ones. The work has been principally based upon a consideration of their light. The quantity of light they reflect is more or less directly measurable.

We know the quantity of light the planets reflect and we know their dimensions. By assuming, therefore, that an asteroid's surface reflects light as intensely as that of some known standard, say the surface of Mars, we can from the known dimensions of Mars deduce the diameter of the asteroid by measuring its brightness.

This, however, is a very uncertain method, for if the surface of the asteroid is more highly reflective than that of our standard the deduced diameter will be too great, and vice versa.

If we compare the albedos, or reflective powers, of the different planets we find a very wide range of albedo. So that if the diameter of any one of them were determined by comparing its light with any of the others, a very erroneous value would be obtained. For instance, Venus has a very highly reflective surface. It reflects light five times as intensely as the surface of the planet Mercury. Therefore, if we should determine the diameter of Mercury photometrically, on the assumption that its albedo was the same as that of Venus, we should get a diameter entirely too small. However, if the size of a celestial body is too small to permit direct measurement, some idea of its size may be had more or less roughly from is stellar brightness.

Dr. Muller of the Astrophysical Observatory at Potsdam, in Germany, has for many years photometrically observed some of the brightest of the asteroids. From these observations he has deduced their diameters on two assumptions. First, that they reflect light surface for surface as intensely as does the planet Mercury. Second, that their albedo is equal to that of Mars.

On the latter assumption he deduces diameters for Ceres and Vesta that are 120 miles greater than with the first assumption. Yet his assumed standards—the albedos of Mercury and Mars—

have a comparatively small range. In the case of Vesta he makes its diameter nearly three times as great as it really is, though having assumed its albedo equal to that of the planet Mercury.

Yet these results of Dr. Muller are certainly the most trustworthy of any obtained by the photometric method.

Some efforts have been made to measure directly the diameters of the four brightest of these bodies. At best, however, these have been but mere guesses, since the instruments used were entirely inadequate to deal with such minute quantities as the diameters of the asteroids. Especially are the earlier attempts in this line extremely discordant.

Schroter measured the diameter of Ceres, and made it 2,025 miles. About the same time Sir William Herschel found from his measures that it was about 100 miles in diameter!

There are not more than one or two instruments in the world capable of properly measuring these small planets. They have aparently not attempted the work, having hopelessly given the asteroids over to the photometric methods It is of the highest importance, however, that a true knowledge of the dimensions of some of the asteroids should be had.

On examining Ceres, Pallas, Juno and Vesta with our thirty-six-inch telescope I found that they presented readily measurable disks, and that their diameters with this noble instrument could be determined with much certainty. I therefore took up their measurement, and have carried on the work for the past two years. The results of this work have just been sent to the Royal Astronomical Society of Great Britain at London. We now know for the first time the true dimensions of these four asteroids.

I have thought these results might be of considerable popular interest if stated briefly. The following are the diameters from the two years' work with the thirty-six inch:

DIAMETERS.

Ceres	485 miles.
Pallas	304 miles.
Juno	118 miles.
Vesta	243 miles.

These will be very close to the true dimensions. Juno was very difficult from its extremely small size. It was at the limit of measurement with the great telescope.

Astronomers have always considered Vesta as the largest of the asteroids, because it was the brightest. In reality it is the

third in size, Ceres being by far the largest. For some reason the surface of Vesta is highly reflective. Its albedo is four times as great as that of Ceres.

Assuming the albedo of Mars to equal 1.00, I have from my measures of these asteroids computed their albedos. These are:

Albedo of Ceres.....0.67
Albedo of Pallas.....0.88
Albedo of Juno.....1.67
Albedo of Vesta.....2.77

Muller has determined the albedos of the planets, which are as follows:

Albedo of Mercury.....0.64
Albedo of Venus.....3.44
Albedo of Mars.....1.00
Albedo of Jupiter.....2.79
Albedo of Saturn.....3.28
Albedo of Uranus.....2.73
Albedo of Neptune.....2.36

That is to say, he has found that the surface of Venus reflects light 3.44 times stronger than that of Mars, etc.

By comparing these albedos of the planets with my results for the asteroids we learn that the surface of Ceres reflects light, area for area, about as intensely as that of Mercury, Pallas somewhat less than that of Mars, Juno between Mars and Jupiter, while the surface of Vesta is as highly reflective as that of Jupiter.

The high albedo of Vesta accounts for its greater brightness compared with its small size. This also accounts for the enormously large diameter attributed to it from photometric observations.

Besides their proper names, the asteroids have each a number assigned them in the order of their discovery. These four are known as Ceres (1), Pallas (2), Juno (3) and Vesta (4).

To show more graphically the relative sizes of these asteroids from my measures of their diameters I have made the enclosed diagram, which will speak for itself. The small circles represent the sizes of Ceres, Pallas, Juno and Vesta as indicated by their numbers—1, 2, 3, 4. The large enclosing circle represents the size of our Moon drawn to the same scale. This perhaps gives the best idea of their real minuteness.

THE PLANETS AND THE CONSTELLATIONS FOR NOVEMBER.

A glance at our diagram shows that after the middle of this month all the planets will be in one half of the celestial sphere. At sunrise all will be above the horizon, at sunset none. *Uranus, Saturn and Mars* are too nearly in line with the Sun to be seen. By the end of the month Saturn will have come out from the Sun's rays far enough to rise about two hours before the latter and so will then be visible.

THE PLANETS AND THE ZODIAC FOR NOVEMBER.

Mercury begins the month near his greatest distance west of the Sun. From the 5th to the 15th he will rise about an hour and forty minutes before the Sun and will then be visible to the naked eye. For the first five days of the month Mercury will move very slowly among the stars and will be about five degrees east from the first magnitude star *Spica*, α Virginis. After that the motion of the planet will be eastward with increasing speed. The planet and the star will be of nearly of the same brightness, so the observer will be on guard not to mistake the one for the other. On November 20 at 4 P. M. Mercury will be in line with and 29′ south of Saturn. On the 23d Mercury will pass by Mars, 1° 13′ to the north of that planet and on the morning of the 26th he will pass 50′ to the north of Uranus. Mars will pass Saturn on the 16th and Uranus on the 29th of November.

Venus is the bright morning planet and is in best position for observation during this month. She will be seen after 3 o'clock A. M. toward the east, among the stars of Virgo, the Virgin. Her apparent motion will be toward the southeast, from a point near the star β to another near the star α. The phase of Venus will be an increasing crescent until the evening of the last day of the month, when she reaches her greatest distance west from the Sun and just half of her disc will be illuminated.

Jupiter is well up toward the zenith in the morning and rivals Venus in brilliancy. He will be found among the faint stars of Cancer, The Crab, moving very little during the month. Jupiter rises a little before 11 P. M. on Nov. 1 and a little before 9 P. M. at the end of the month, so that we shall soon be able to observe this planet in the evening.

Neptune is the only planet which is in position for good observation before midnight, and this one is too faint to be seen without a good telescope. One needs to set his telescope by accurate circles in order to be sure of seeing the planet, for it is not distinguishable from the multitude of equally bright stars by its appearance, except in the more powerful telescopes. The place of Neptune on Nov 15 is: Right Ascension $5^h\ 5^m.4$; Declination north 21° 22′; and its motion is so slow that this place will serve for the whole month. This is in the constellation Taurus about one third of the way on a line from the star ι to the star ζ. Neptune is about equal in brightness to a star of the eighth magnitude. H. C. W.

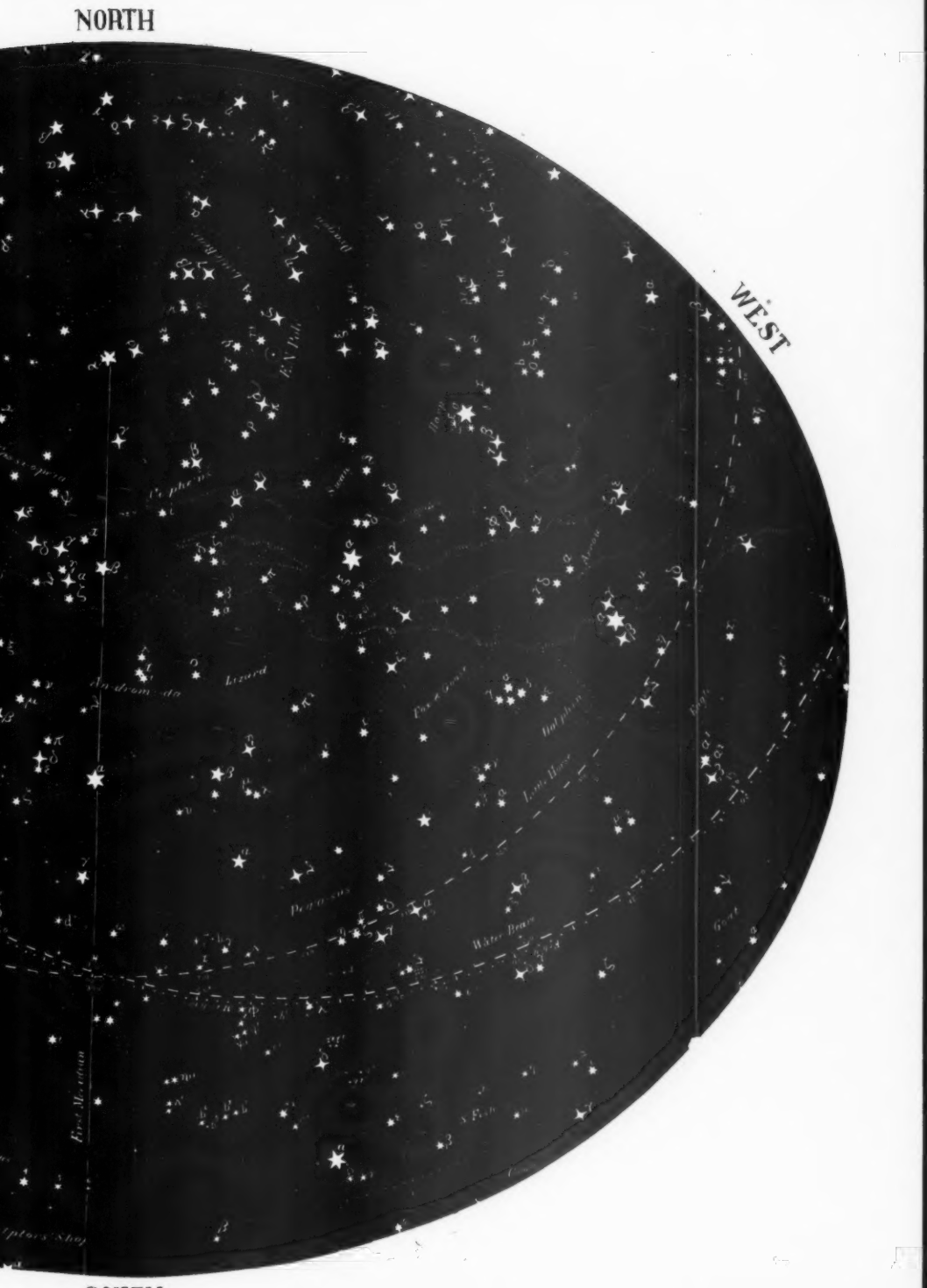
The map which we present in this number of POPULAR ASTRONOMY shows the stars which are visible to the naked eye in our latitude at 9 o'clock P. M. on November 1. In order to use this map for identifying the stars in the sky, hold it with the proper point of the horizon toward yourself, *i. e.* if you are looking toward the south hold the mapwith the word south nearest you, or if toward the west, with the word west nearest you. Then, remembering that the stars in the center of the map are exactly over head, you will easily be able to compare the stars in the sky with their counterparts on the map.

Looking first toward the south at 9 o'clock we shall see a very bright star a little to the west of the meridian and down near the horizon. This on the map is marked α in the constellation of the Southern Fish. North of this are only inconspicuous stars until the eye reaches the large square of Pegasus, about three-fourths of the way up to the zenith. The four stars forming the square are marked on the map α, β and γ of Pegasus, and α of Andromeda. The last is the brightest of the four. Near β is another star, η, nearly as bright. With these to start with the reader will easily identify the fainter stars.

Turning to the west one will see three first magnitude stars forming a great triangle, Altair, α of the Eagle (*Aquila*), Vega, α of the Harp (*Lyra*) and Deneb, α of the Swan (*Cygnus*). The lower left hand star in the triangle is α of the Eagle; β and γ on either side of it form a straight line. The lower right hand star is α of the Harp: the faint stars ε and ζ form with α an equilateral triangle. ε is the famous double star; to the naked eye it is single or barely elongated: with a small telescope a wide double and with high magnifying power both components double. Just midway between γ and β of the Harp is the wonderful Ring Nebula. It is very small and faint in a small telescope but in a large one it is a bright and strange object. The upper star of the great triangle, α of the Swan, is in the middle of the Milky Way; α, γ and β mark the body and neck, δ and ε the wings of the Swan. The region from γ to β is one of the richest in stars in the whole sky.

Toward the north the eye will catch first the seven bright stars of the Great Bear or Great Dipper, close to the horizon. Half way up to the zenith is the Pole star, Polaris, not exactly at the pole of the heavens but on the edge of a circle a little over two degrees in diameter. Polaris is α of the Little Bear and is situated at the end of the tail of that animal, whose body extends down toward the northwest, marked by the stars ε, ζ, η, γ and β. To the west of the Little Bear is the Dragon, his head marked by the stars β, γ, ξ, ν and μ, the tail curving upward

Planisphere Map of the Constell



Constellations for 9 o'clock p. m. November 1.

around the north pole of the ecliptic, then downward and to the right between the two Bears. The bright group between the pole and the zenith is Cassiopeia's Chair.

Toward the east two conspicuous stars will at once strike the eye. The higher and brighter one is Capella, α of the Wagoner (*Auriga*). A good sized polygon of fairly bright stars marks this constellation so that it can readily be fixed in mind. The other conspicuous star is Aldebaran, α of the Bull (*Taurus*), a red star accompanied by a V shaped group of bright stars, ϑ, γ, δ, ε, known as the Hyades. The familiar group of the Pleiades is in the same constellation a short distance northwest of the Hyades. The brightest star of the group is marked η on the map. The star just at the eastern horizon is Betelgeux, α of of Orion.

Having now identified all the bright stars it will be an easy matter to pick out the fainter ones and give them their right names by letter. One of the most important things to do this month will be to find the exact place of o of the Whale (*Cetus*), which is the wonderful variable star *Mira*. The Whale is such a large rambling constellation with no definite outlines that it is hard to trace it, but the place of o can be got at easily by means of the Fishes. Beginning with β of Andromeda a long curve of faint stars sweeps down toward the east to α of the Fishes; another long line of similar stars begins below the Square of Pegasus and running eastward meets the first in α. The narrow V formed by the two lines of the Fishes points directly toward the place of o Ceti which is marked on the map. As stated in another note Mira is not visible to the eye now, but toward the end of the month it should become conspicuous. H. C. W

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

	d	h
Dec.	3	10
	8	10
	13	9
	18	9
	23	9
	28	8

ALGOL.

Dec.	2	5
	13	16
	16	13
	19	10
	22	7

λ TAURI.

Dec.	1	12
	5	11
	9	10
	13	9

ζ TAURI CONT.

d	h
17	8
21	6
25	5

R CANIS MAJ.

Dec.	4	9
	5	12
	6	15
	12	8
	13	11
	14	14
	15	17
	21	10
	22	13
	23	16
	29	9
	30	12
	31	15

S CANCRI.

	d	h
Dec.	1	13
	20	12

δ LIBRÆ.

Dec.	7	17
	14	17
	21	16
	28	16

U CORONÆ.

Dec.	5	15
	12	13

U OPHIUCHI.

	d	h
Dec.	2	8
	7	9
	13	6
	15	18
	18	6

Y CYGNI.

Even Epochs.

Dec.	3	8
	6	8
	9	8
	12	8
	15	8
	18	8
	21	8
	24	8
	27	8
	30	8

From Dr. Hartwig's ephemeris in the *Vierteljahrsschrift*. J. A. PARKHURST. Marengo, Ill., 1895, Oct. 9.

Ephemeris of Short-Period Variables.

The following ephemeris of variable stars of short period is given in the hope of stimulating some effort toward their observation.

The times of maximum and minimum are computed from the elements given in Chandler's Second Catalogue, with the exception of the cases of β Lyræ, which is taken from the Companion to the "Observatory."

It is intended to continue this ephemeris from month to month.

NOVEMBER.

[Greenwich Mean Time].

2279 T Monocerotis.

Max.	Min.
24.34	16.41

2509 ζ Geminorum.

Max.	Min.
5.97	11.11
16.12	21.26
26.28	

6758 β Lyræ.

Min.
6.17
19.08

6984 U Aquilæ.

Max.	Min.
2 68	7.46
9.71	14.49
16.74	21.51
23.76	28.54
30.79	

7124 η Aquilæ.

Max.	Min.
2.73	6.53
9.90	13.70
17.08	20 87
24.25	28.05

7149 T Sagittæ.

Max.	Min.
3.98	8 96
12.37	17.35
20.75	25.73
29.13	

7437 X Cygni.

Max.	Min.
3.13	12.72
19.52	29.11

7483 T Vulpeculæ.

Max.	Min.
1.94	5.08
6.38	9.52
10.82	13.95
15 26	18.39
19 69	22.82
24.12	27.26
28 56	

8073 δ Cephei.

Max.	Min.
1 23	5.08
6.59	10 45
11.96	15.82
17.33	21.18
22.69	26.55
26.06	

Dorchester, Mass., 1895, Oct. 9. PAUL S. YENDELL.

5484 U Coronæ.—On the evenings of Sept. 10th and 17th I observed this star within an hour of the computed times of minimum, finding it at $8^m.8$ and $8^m.9$ respectively; although my observations were not numerous enough to definitely fix the time of minimum, they are enough to show that it was not far from the prediction.

The changes in the periods of the stars of the Algol type, are slow and regular and for the most part periodical (probably in all, but the evidence thus far collected is insufficient to prove this); and a sudden change in their period is not more probable than in the Earth's rotation-period.

According to Winnecke's mean light-curve, which is the only one yet published so far as I know, and which agrees with my own observations of the star, there is no stationary period at minimum, the turn being quite definite. In fact, the old statement that Algol remains at the minimum light for 20 minutes is incorrect, and there is no star of the class in which this occurs; the nearest approach to it is in the cases of U Cephei and S Cancri, both of which stars increase very slowly for a considerable interval after the point of minimum light has been passed. P. S. Y.

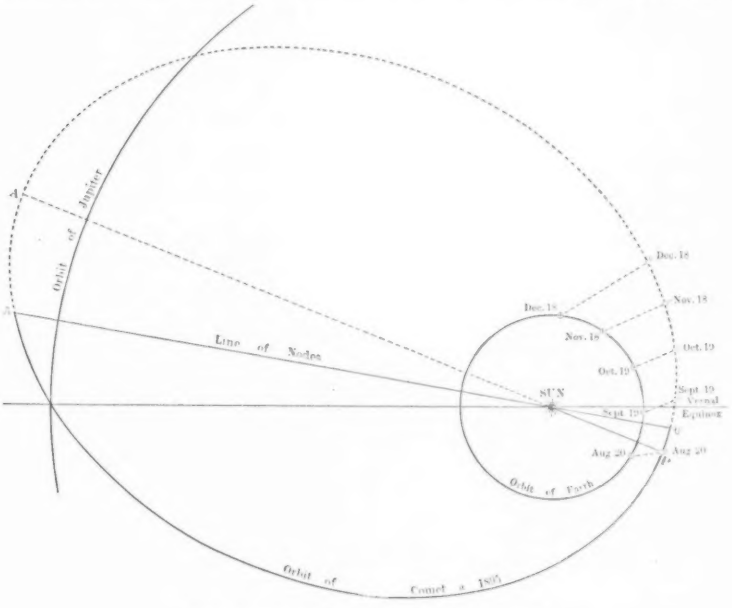
The Variable Star Mira *o* Ceti.—On the night of Oct. 16 I observed this variable star with the 16-inch telescope of Goodsell Observatory, and measured the position-angle and distance of the 9.5 magnitude companion star. The position-angle is 80°.9 and the distance 116″.67. The two stars are now almost exactly equal in magnitude. Mira is of a reddish color while the companion is bluish white.

Photographs taken with the 8-inch telescope Oct. 16 and Oct. 17 with exposures of 10^m and 60^m respectively, agree in making Mira slightly brighter than the companion, contrary to my expectation from the visual observation.

In November Mira should begin to increase in brightness, reaching maximum, according to Mr. Parkhurst's ephemeris in our last number, on December 9. As this star is now very favorably situated for observation doubtless many of our readers will be able to watch the coming rise and fall of brightness in the *wonderful* variable. According to Chandler's Catalogue the brightness which Mira attains at different maxima is not the same but is sometimes that of a second magnitude and sometimes only a fifth magnitude star. H. C. W.

COMET NOTES.

New Elliptical Elements of Swift's Comet.—Both Professor Boss and Dr. Berberich have computed new elements of the comet's orbit and find the period to be a little over 7 years, so that it undoubtedly belongs to the Jupiter



THE ORBIT OF SWIFT'S COMET *a* 1895.

family of comets. It is still visible in a large telescope, its brightness being about half that at the time of discovery. The following are the latest elements:

Computer.	Boss.	Berberich.
Time of Perihelion $= T =$	Aug. 20.75426	Aug 20 84759 Gr. M. T.
Longitude of Perihelion $= \pi =$	338° 0′ 26″.1	338° 3′ 25.1
Longitude of Node $= \upsilon =$	170° 18′ 6″.8	170° 16′ 17″.3
Inclination to Ecliptic $= i =$	3° 0′ 11″.1	2° 59′ 24″.9
$\varphi =$	40° 44′ 17″.2	40° 22′ 17″.6
Eccentricity $= e =$	0.652603	0.647741
Mean daily motion $= \mu =$	491″.590	502″.654
Semimajor axis $= a =$	3.73482	3 67981
Period	7.22 years	7.06 years.

Professor Boss gives the following ephemeris for the first few days of November. The comet is moving slowly eastward in the southeast corner of the constellation Pisces.

EPHEMERIS OF SWIFT'S COMET.

Greenwich Midnight.	R. A.			Decl.			Log Δ
	h	m	s	°	′	″	
Nov. 1	1	28	41.7	+ 3	28	34	9.7678
3		29	10.2	3	31	9	9.7805
5		29	42.5	3	34	36	9.7933
7		30	18.8	3	38	53	9.8062
9		30	59.3	3	43	59	9.8192
11	1	31	44.1	+ 3	49	53	9.8322

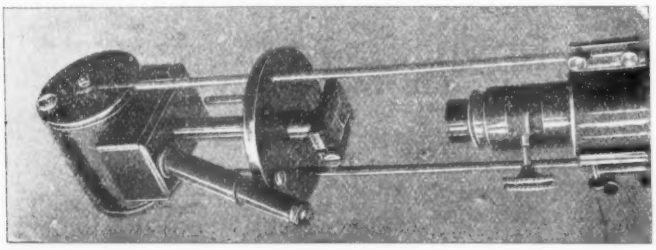
The Return of Faye's Periodic Comet.—This comet is due at perihelion in March 1896 but has already passed its point of nearest approach to the Earth. It is reported to have been seen on Sept. 26 with the 30-inch telescope at Nice. We have searched carefully for it with the 16-inch telescope at Northfield but failed to see it. No reports of observations elsewhere have yet come to hand.

H. C. W.

PRACTICAL SUGGESTIONS

Spectroscope for Small Telescope.—In the October number of POPULAR ASTRONOMY I gave a description of a grating spectroscope for a small telescope, of my own make, which was illustrated by a cut of the instrument showing the grating attached to one end of the grating box which was removed.

The illustration presented herewith shows the spectroscope in place, attached to the telescope.



To some recent inquiries from amateurs regarding its use for solar work, I will say that the chromosphere and prominences are easily and well seen, also the occasional reversals and distortion of lines in spot spectra.

In order to keep the edge of the Sun's image exactly tangent to the edge of the slit or a spot between the slit jaws, I have depended altogether on the right ascension slow motion rod used by hand.

A driving clock of some form would certainly be a great convenience, but is not absolutely indispensable for viewing the prominences. A good equatorial mounting, however, is essential.

DAVID E. HADDEN.

Alta, Iowa, October 15, 1895.

127. Would it be possible to lay out in your magazine a course of study that would prepare one for the usual college course in astronomy?

Answer:—Certainly; this will be attempted in part, at least, next month. In the mean time we especially ask those who have had experience in teaching astronomy in colleges and universities to aid us, by calling attention to the essentials belonging to such a preparation in the light of their experience.

The Constant of Gravitation—Professor C. A. Young says that the person who wrote on the "Constant of Gravitation" in our April number, (pp.. 281-2) is in error in saying (at the top of page 282) that the value of k depends upon "the assumed value of the mean radius of the Earth and upon the *mass* of the Earth." He says we get the mass of the Earth best from observations (of Torsion balance) that give *directly* the value of k or of G (not g) if we use Boys' notation. In getting the Earth's mass from such observations combined with the valve of g, we do not usually stop to determine k, (or G) but eliminate it

In the observations of the Tortion balance in recent work f is usually measured in grammes (or mgs) by the torsion, while D is measured directly in centimetres and M_1 and m_2 in grammes. Boys' experiments of 1893 (see *Nature*, Vol. 50, pp. 330, 366, 317) are the latest and most elaborate, and give $G = 0.000\ 000\ 06576$—that is two globes of one gram each, centers 1 c. m. distant would attract each other with a force of 0.000 000 066 of a dyne. The result would have been the same if the experiments had been on Mars or the Moon.

We are glad to call attention to the explanation of this constant again for distinguished physicists in the United States are not all correct in their explanations of the exact meaning of k and G. To bring this matter to the attention of teachers and students in definite and authoritative way still further, we have decided to republish parts, at least, of that excellent address by C. V. Boys referred to by Professor Young. The introductory part of it is given elsewhere in this number.

GENERAL NOTES.

The response in renewals for volume III of this publication is general and very encouraging. If numbers have failed to reach any, it may be because renewal has not been ordered, or because names have been overlooked in re-writing the lists.

Some illustrated, popular articles have been necessarily deferred until next month, for lack of time to secure the engraving. As it is we have added eight pages to our usual size in order to give forty-eight pages of popular and elementary matter, and also to give some articles for the amateurs who are rapidly learning the ways of the practical astronomer. They need the help and we are sure our general readers will encourage us in such a course.

Otto I. Klotz, of Ottawa, Canada, at present member of the International Boundary Commission, for survey of the boundary line between Alaska and British America, has written an article for this publication on the determination of latitude by elongation. It will be given next time.

Liquefaction of Argon and Helium.—From *Science*, Oct. 18, 1895, we notice that Professor Ramsay has received "a letter from Professor Olszewski, of Krakau, in which he informs him that having exposed a sample of helium which he sent him to the same treatment as was successful in liquefying hydrogen—namely compressing with a pressure of 140 atmospheres, cooling to the temperature of air boiling at low pressure, and then expanding suddenly—he has been unable to detect any sign of liquefaction. The density of helium being, roughly speaking, twice that of hydrogen, it is very striking that its liquefying point should lie below that of hydrogen. It may be remembered that argon which has a higher density than oxygen, liquefies at a lower temperature than oxygen; and it was pointed out by Professor Olszewski that this behavior was not improbably connected with its apparently simple molecular constitution. The similar fact now recorded for helium may therefore be regarded as evidence of its simple molecular constitution."

The Herschels and Modern Astronomy is the title of a new book by Agnes M. Clerke, the well known author of "A Popular History of Astronomy during the 19th Century," "The System of the Stars," etc., etc. The contents of this delightful little book is presented in ten chapters whose titles are: 1. Early Life of William Herschel; 2. The King's Astronomer; 3. The Explorer of the heavens; 4. Herschel's Special Investigations; 5. The Influence of Herschel's Career on Modern Astronomy; 6. Caroline Herschel; 7. Sir John Herschel at Cambridge and Slough; 8. Expedition to the Cape; 9. Life at Collingwood; 10. Writings and Experimental Investigations.

Readers of this book will find, as those acquainted with Miss Clerke's earlier books already know, a comprehensive and a concise treatment of the theme in hand. It is always a gratification to a scholarly reader to find a book that is exact in statement without being ambiguous or diffuse, and to know that an author has selected the very best of the material available and then with masterful insight has put it in right order for instruction and edification. So far as we know this book is a good example of this, although it must be confessed that the task was not an easy one, by any means, because in the case of William Herschel the amount of material available for such a book is so great, while in that of John Herschel his history yet remains to be written. The former the author condenses into five chapters and 114 pages, and the latter appears in four chapters embracing 123 pages. Between the two accounts, in a single chapter, is presented fittingly the beautiful life and the eminently useful services of Caroline Herschel. This book is an excellent one for young people to read because of the models it furnishes for those who may be looking to scientific studies or pursuits. It is a useful volume for the teacher's desk because in the briefest compass it imparts a knowledge of the true spirit in which an ardent purpose grows into power and usefulness and soon unconsciously is moulded into a great life. It is also a book that the busy astronomer will stop to read, and will not leave till he is through it, because he loves to go over and over again the paths of these illustrious people and see how the great battles of their lives were won and finally crowned with such signal victory.

We wish also to remind our readers that this volume is the third in the "Century Science Series" which is rightly claiming wide attention because of the real merit of the series. The publishers are Messrs. Macmillan & Co., 66 Fifth Avenue, New York. Price of book $1.25.

What Prominent Astronomers are Doing.—Professor G. W. Hough, Director of Dearborn Observatory, Evanston, Ill., is now engaged in the discovery and measurement of double stars. Since the publication of his third catalogue of new double stars he has discovered a considerable number of very close pairs. The measures are mostly confined to the stars of his own catalogue which are difficult binaries.

He has recently begun the systematic observation of markings on the planet Jupiter in continuation of his work of the same kind which he has been diligently pursuing for the past sixteen years. Professor Hough says the great red spot which was fairly well seen during the last opposition is not yet visible, but that there is a notch or depression in the equatorial belt north of the position the spot ought to occupy. He also says that the results of his observations in regard to the motions of the great red spot from 1879 to date will soon be ready for publication. These results will doubtless convey important information as to the real character of this very strange marking on the surface of this planet.

Professor William Harkness, Astronomical Director of the United States Naval Observatory, Washington, D. C., recently speaking of the work now in progress at that institution says:

All the large instruments belonging to this Observatory are now actively employed whenever the weather permits. The 9-inch transit circle is used for observing the Sun, Moon, planets and the zone of stars situated between 13° 50′ and 18° 10′ of south declination. The prime vertical transit instrument is used for observing a list of stars selected to improve our knowledge of the constants of aberration and nutation, and to detect any possible variation of latitude, and an independent determination of the latter element is also made with a small meridian instrument used as a zenith telescope. Finally, the 9½ and 26-inch equatorial telescopes are used for hunting up asteroids when the ephemerides are imperfect; for observing the satellites of the outer planets, and for observing comets, double stars, occultations of stars by the Moon and eclipses of Jupiter's satellites.

Harvard College Observatory.—In the absence of Professor E. C. Pickering (who has been in Europe during the summer) Arthur Searle has given us some information concerning present work at the Observatory.

The visual work with the equatorial telescopes is chiefly the observation of variable stars and stars to be compared with them, both by photometric means and by estimates on Argelander's method; the zone observations with the Meridian Circle, from — 10° to — 14° are to be resumed as soon as the progress of the reductions furnishes sufficient material for revision; the photometric work both here and in Peru continues to provide numerous records of the stars and their spectra, according to the plans explained in the last annual report of the Observatory.

Smith Observatory.—The following report is from Smith Observatory, Geneva, N. Y., by the Director, Professor Wm. R. Brooks:

In response to your request, I would say that, in accordance with the wishes of its founder, an important part of the work of this Observatory is the entertainment and instruction of visitors. The Observatory is freely open to the public on *every clear week-day evening*, no tickets or other restrictions being imposed. The Observatory is not opened on Sundays. Large numbers of persons

avail themselves of this great privilege, not only from our own Geneva—a place of 10,000 inhabitants—but from all the surrounding towns, and from the most distant states and cities. Many persons come from distant cities and sojourn here at our hotels for a few days to visit the Observatory. The work has proven itself to be of great educational value.

In the intervals of this work, or at a late hour of the night after the visitors have departed, only can my own individual researches be carried on. This is graphically illustrated by the fact, as shown by the record, that all but one of my Geneva comets have been discovered in the morning sky.

Comet seeking, and in connection therewith the formation of a chart-catalogue of all nebulæ visible with the 10½-inch equatorial in the northern hemisphere, and to 30° of south declination. The position of each nebula is secured, and in connection therewith a chart of the telescopic field showing the principal telescopic stars in their relative positions with nebula.

Astronomical photography with the 10½-inch equatorial, which has a photo-correcting lens of similar aperture, and also with a portrait lens of 3 inches aperture, receives such attention as my other duties will allow. Photographs of important sunspots are also frequently made. These with the Moon are usually made by direct enlargement in the telescope to 4½-inches in diameter; and also to a scale of 36-inches disc for the solar disc. A fine series of plates was secured of the recent eclipse of the Moon Sept. 3-4. Observations for time are also made with the meridian circle. This time reduced to that of the 75th meridian standard time is furnished free to Geneva.

Physical observation of the planets and comets and double star measurements receive attention.

Frequent illustrated lectures are given freely to the public and before the pupils and teachers of the high school. These latter are always upon some topic of current interest and are given when all are assembled for chapel exercises at the opening of the morning session, and are received with great interest and appreciation. The public press is also furnished with frequent astronomical notes.

WILLIAM R. BROOKS.

New Editions of Professor Young's Books.—Professor C. A. Young calls our attention to a slight error of statement in regard to the new editions of "The Lessons" and "The Sun," as given in our last issue. We should have said that the copy for the revised editions for both of these books is now in the hands of the printer. The work of revision of the "Elements of Astronomy" and the "General Astronomy" remains to be done.

Astronomical Observation by B. D'Engelhardt of Dresden Vol. 3, has just come to hand. It is a fine quarto volume of 189 pages and, in appearance companions of the two previous volumes. The work of this volume consists of measures of the satellites of Saturn, various observations of important phenomena of recent years, such as comets, eclipses, transit of Mercury, new star in Auriga and minor planets. A large portion of the volume is given to observations for determining the places of nebulæ for the present year, with full references to authorities and extended notes relating to the observations made by the author. The volume also contains a list of measures of double stars, and a list of corrections to matter published in volumes I and II.

The American Association for the Advancement of Science.—The

annual meeting of this association for 1895 was held at Springfield, Mass., during last week in August. The meeting for 1896 will be at Buffalo, N. Y. In Mr. J. Riechie's report of the last meeting, as published in the *Boston Commonwealth*, the following points are noted: That the last meeting marked, probably, a crisis in the history of the association; that, although the younger members were active and have maintained the high character of previous sessions, yet it has been manifest for several years that the association is losing the position it has held as the recognized representative of American science. "This is shown by a decreasing membership and a decreasing attendance. Of nineteen past presidents, four were present at the last meeting." Nine vice presidents are elected each year, of the entire number so elected only nineteen were present. Though the place of meeting was central for New England, leading instructors from the colleges were few in number: Columbia 7, Harvard 6, Wesleyan 3, Worcester Polytechnic, Amherst, Yale, 2 each and several other colleges only one each. By states, N. Y. 92, Mass. 69, District of Columbia 29, Ohio 21, Conn. 19, Indiana 14, Mich. 11, and from twenty one other states numbers are each less than ten.

In view of the facts of decreasing membership and attendance, a committee of eleven members was appointed to which the consideration of the whole matter was referred. The report of this committee which may suggest some reforms in the management of the association will be looked for, we imagine, with some interest by the old ex-members and ex-fellows who have not regularly attended the meetings for eight or ten years.

Columbia College Observatory—J. K. Rees, Professor of Astronomy, and Director of the Observatory, Columbia College, N. Y., writes concerning the work going on in that Observatory now, as follows:

(1). That we are continuing to observe for variation of latitude. M. Fergola, the Director of the Royal Observatory at Naples, is observing the same stars.

The two observatories began the work, May, 1893.

(2). Dr. Davis, of the Observatory staff, is passing through the press Memoir I Part I of the publications of the N. Y. Academy of Sciences on "The Declinations of 56 stars." These are the stars used here and at Naples in our latitude work.

(3). Professor Jacoby has returned from his leave of absence. He visited many of the observatories abroad but spent most of his time at the Royal Observatory at the Cape of Good Hope. He has brought back with him several very important pieces of work This year our new Repsold measuring machine (presented to the Observatory by the late L. M. Rutherfurd's son) will be used under Professor Jacoby's direction in investigating photographs of polar stars, north and south for the purpose of learning something about the optical distortion of the object-glasses used.

(4). Dr. Davis is at work on the Rutherfurd measures of the photographs presented to our Observatory.

(5). Professor Rees says that eight students are pursuing the Practical Astronomy course, sixteen are in the descriptive course and thirty-five are in the engineering course in Geodesy and Practical Astronomy.

Littell's Living Age, a most excellent weekly publication is reduced in price from $8 to $6 a year. By clubbing with POPULAR ASTRONOMY the two cost only $7.50.

E. E. Barnard Leaving Lick Observatory.—Our attention has been called to the circumstances attending the recent departure of E. E. Barnard from Lick Observatory and from San Francisco. We have received from different sources a number of letters about it during the last few weeks, with newspaper accounts of the various banquets tendered in his honor. Some of these letters are hearty and strong in commendation of Mr. Barnard and from persons in prominent places in California who speak very explicitly of the unjust treatment which he has received from some unfriendly to him. We have also received two letters from one person, we think, a reporter for one of the San Francisco papers who is said to be the author of certain articles apparently intended to be damaging to Mr. Barnard. Although this view of the matter is wholly disclaimed by the author in a private letter, yet the meaning and the intention of those articles are too transparent to deceive anybody who understands the situation. With such low grade newspaper higgling we will have nothing to do, and our advice to the friends of Mr. Barnard is to ignore wholly all such weak methods of attack, no matter who is the source or the inspiration of them. If Mr. Barnard is either wrongfully the cause of the strained relations that have existed between members of the Lick Observatory staff, or, is lacking in professional ability as has been repeatedly intimated, there are better ways to set such things right than the ones chosen. On the other hand, if Mr. Barnard is not the cause of the trouble referred to, and, is a reputable astronomer then the treatment he has received, (if we are rightly informed) is a shame and an open disgrace. Mr. Barnard explicitly says to us that the charges against him are not true and apparently explains all to our satisfaction. Director Holden knows whether these representations affecting the scientific standing and character of Mr. Barnard are true or false. Nobody has had a better opportunity than he to know all the circumstances. If they are true is it not due to his position and to science to say so publicly in the right spirit? If these things are not true every consideration belonging to professional position dignity, courtesy or common regard would seem to demand that he shield an inferior in place from injustice or disgrace in a position which he himself honorably bestowed on Mr. Barnard years ago.

In Popular Astronomy for September, I read a letter from Mr. Alfred Bicknell, of Boston, with regard to popularizing astronomy. I have found from experience that a conversational way of lecturing, is decidedly popular, and I have found it possible to hold the attention of even small children, for an entire hour, whilst discoursing upon the wonders of the heavens. It is the same with my advanced lectures, conversational lectures are always preferred to "manuscript lectures," as they are sometimes called. It is far more difficult to give such lectures, as it is a great strain mentally, but it is worth while, when we feel that the audience is following every word we are saying. Besides, unhampered by reading manuscript, we are able to determine whether we are making the lecture interesting or not. This is most important. To give such lectures, a thorough knowledge of the subject, and a good command of language is absolutely necessary, and with these acquirements it is possible to bring astronomy within the reach of all. My father was undoubtedly eminently successful in this way, and it is my ambition to carry on his work, though I expect many years of study and experience must pass before I am successful. However we can but do our best, and we must not expect to run, before we have learned to walk. MARY PROCTOR.

Meteors Seen During a Solar Eclipse.—In the March number of POPULAR ASTRONOMY, G. D. gives from the Superintendent's Annual Report, testimonials of several parties who had observed a shower of meteors during the total solar eclipse of 1869.

During my observation of that eclipse at Mattoon, Illinois, I, myself, witnessed the same phenomenon, but it took only a moment's reflection to convince me that the bodies seen were not meteors at all but thistle down moving in the same direction towards which the wind at the time was blowing. I saw the same objects float across my telescope at the eclipse of 1878, at Denver, Colorado, but at that of 1890, viewed from a station in northern California in the winter, I saw none. It is not an unusual occurrence thus to see them without an eclipse, especially in bright sunlight.

I recall that a few years since Mr. H. C. Maine, of Rochester, N. Y., came to me by day and announced a meteoric shower in progress, and that he had seen several meteors through his telescope. I related to him my experience with thistle-down as detailed above, but at his urgent request, accompanied him to his home, a mile away, where, in a short time, two or three of these so-called meteors were seen to pass the field of the telescope, moving with the wind. He was very soon led to adopt my conclusion regarding them.

If not too much out of focus, even insects are often visible during the summer months, but, in the winter, neither they nor the thistle down will be seen passing the field of the instrument.

My surprise is that any astronomer should be deceived in so simple a matter when it is so improbable that a meteoric shower can be seen on the Earth's sunny side.

Lowe Observatory, Echo Mountain, Cal. LEWIS SWIFT.

Alvan Clark of Cambridgeport, Mass , is now at work on a twenty-four inch object-glass for Percival Lowell, which with its mounting must be completed at a given date, in June next, to be in readiness for the observation of Mars at its coming opposition. It is not yet decided where this new, large telescope will be located.

The Great Object-Glass For the Yerkes Observatory of the University of Chicago is still at the shop of Alvan Clark in Cambridgeport, Mass. It probably will not be mounted at Lake Geneva before the spring of 1896.

A Large Meteor.—On suggestion of Mr. W. C. Winlock of the Smithsonian Institution, I send you the following:

A large meteor was seen a little north of west from this place about 9:20 P. M., Oct. 10th. Several unusually bright shooting stars had already been observed in different parts of the heavens when this much larger one appeared. It seemed like a near-by descending rocket, falling northward in a slightly curved line at an average angle of about 30° from perpendicular. When first noticed its altitude was about 45°. It consisted of a very brilliant ball of blue color, edged with a lighter yellowish red, and followed by a trail of small stars or sparks, seemingly thrown off from the main body.

The meteor was so brilliant as to light up objects and attract attention to itself by its power of illumination.

It was visible for only a few seconds—say ten or fifteen—and then passed from view, either beyond the distant horizon, or the nearer trees.

CHARLES P. ARNOLD.

Angelica, N. Y., Oct. 16, '95.

Astronomical and Physical Society of Toronto.—At a recent meeting of the Astronomical and Physical Society of Toronto, Canada, a drawing of the Saturnian system was presented by Miss E. M. Brook, of Simcoe, Ont. This drawing had been made at a 12-inch reflector, and showed a concave outline of the shadow of the planet upon the ring. It had been carefully studied by Mr. Arthur Harvey, who gave a demonstration of the fact that, granting the accuracy of the drawing, a section of Saturn's ring must be either lenticular or elliptical—the ellipse having its major axis perhaps eight or ten times as long as the minor. Usually the rings have been spoken of heretofore as plates—flat, and of an even thickness. Mr. Harvey showed, however, from the principles of projection, that if the rings were flat the edge of the shadow on them would in effect be elliptical, with curvature toward the planet. The conclusion reached by Mr. Harvey in his paper, profusely illustrated by diagrams and a model of the system, was that the rings have elliptical sections, the inner ring being much the thicker. Following Professor Keeler's confirmation by spectroscopy of Clerk-Maxwell's theoretical proof that the rings must be composed of innumerable solid independent bodies, the inner moving faster than the outer, this new observation and its deduction reveal another interesting fact connected with the solar system. Therefore, it becomes important to verify the observation. In any event, this method of ascertaining the nature of the surface of the rings, whether plane or curved, and if curved to what degree, by the observation of the form of the edge of the shadow thereon is apparently new. JOHN A. COPELAND, Foreign Cor. Sec. A. P. S.

The Number of the Asteroids.—The asteroids whose orbits have been determined now number 404. The latest to receive numbers are:

(402) = 1895 *BW* discovered by Charlois March 21.
(403) = 1895 *BX* " " " May 18.
(404) = 1895 *BY* " " " June 20

The latest discovered *BZ* and *CA* July 23 and *CB* Aug. 22, all by Charlois at Nice, have not yet been numbered.

The Toronto Globe is doing excellent service for Popular Atronomy. Its issue of Aug. 10 contained nearly two full pages with sixteen fine cuts of buildings, instruments and men, exemplifying the earnest and progressive study of astronomy in Canada.

Elementary algebra by H. S. Hall and S. R. Knight. Revised and enlarged by F. L. Sevenoak of Stevens Institute of Technology. Published by Messrs. Macmillan & Co., New York and London, 1895. pp. 478.

We have been interested to examine Professor Sevenoak's revision of Hall and Knight's elementary algebra, for the appearance of the book was suggestive of unusual amount and variety for an elementary work on algebra for American schools.

In the first chapter of eight pages treating of definitions and substitutions, there are 136 examples. Exercises, examples and graded problems are more freely used than in any other similar book we know of.

This work contains much that is usually given in the so called higher algebras; for example, exponential and logarithmic series, interpolation, determinants, theory of equations and many more such topics.

This algebra seems sufficient for the ordinary college course, and it is evidently sufficient for entrance to any technical school. Teachers will be interested in this book.